JOURNAL

AND

PROCEEDINGS

OF THE

ROYAL SOCIETY

OF

NEW SOUTH WALES

1927

(INCORPORATED 1881.)

VOL. LXI.

EDITED BY

THE HONORARY SECRETARIES.

THE AUTHORS OF PAPERS ARE ALONE RESPONSIBLE FOR THE STATEMENTS MADE AND THE OPINIONS EXPRESSED THEREIN.

SYDNEY:

PUBLISHED BY THE SOCIETY, 5 ELIZABETH STREET, SYDNEY.

ISSUED AS A COMPLETE VOLUME, MAY, 1928

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NOTICE.

The Royal Society of New South Wales originated in 1821 as the "Philosophical Society of Australasia"; after an interval of inactivity, it was resuscitated in 1850, under the name of the "Australian Philosophical Society," by which title it was known until 1856, when the name was changed to the "Philosophical Society of New South Wales"; in 1866, by the sanction of Her Most Gracious Majesty Queen Victoria, it assumed its present title, and was incorporated by Act of the Parliament of New South Wales in 1881.

TO AUTHORS.

Authors should submit their papers in typescript and in a condition ready for printing All physico-chemical symbols and mathematical formulæ should be so clearly written that the compositor should find no difficulty in reading the manuscript. Sectional headings and tabular matter should not be underlined. Pen-illustrations accompanying papers should be made with black Indian ink upon smooth white Bristol board. Lettering and numbers should be such that, when the illustration or graph is reduced to $3\frac{1}{2}$ inches in width, the lettering will be quite legible On graphs and text figures any lettering may be lightly inserted in pencil Microphotographs should be rectangular rather than circular, to obviate too great a reduction. The size of a full page plate in the Journal is $4 \times 6\frac{1}{4}$ inches, and the general reduction of illustrations to this limit should be considered by authors. When drawings, etc, are submitted in a state unsuitable for reproduction, the cost of the preparation of such drawings for the process-block maker must be borne by the author. The cost of colouring plates or maps must also be borne by the author.

ERRATA.

Page 868, Fig. 1.—For fracheid read tracheid.
Page 869, Fig. 2.—For fracheid read tracheid.

FORM OF BEQUEST.

I bequeath the sum of £ to the Royal Society of New South Wales, Incorporated by Act of the Parliament of New South Wales in 1881, and I declare that the receipt of the Treasurer for the time being of the said Corporation shall be an effectual discharge for the said Bequest, which I direct to be paid within calendar months after my decease, without any reduction whatsoever, whether on account of Legacy Duty thereon or otherwise, out of such part of my estate as may be lawfully applied for that purpose.

[*Those persons who feel disposed to benefit the Royal Society of New South Wales by Legacies, are recommended to instruct their Solicitors to adopt the above Form of Bequest.*]

LIST OF THE MEMBERS

OF THE

Royal Society of New South Wales.

P Members who have contributed papers which have been published in the Society's Journal. The numerals indicate the number of such contributions.

‡ Life Members.

Elected.		
1908		Abbott, George Henry, B.A., M.B., Ch.M., 185 Macquarie-street; p.r. 'Cooringa,' 252 Liverpool Road, Summer Hill.
1904		Adams, William John, M.I.Mech.E., 175 Clarence-street.
1898		Alexander, Frank Lee, William-street, Granville
1905	P 8	Anderson, Charles, M.A., D.Sc. *Edin.*, Director of the Australian Museum, College-street. (President, 1924.) *Vice-President.*
1909	P 9	Andrews, Ernest C., B.A., F.G.S., Hon. Mem. Washington Academy of Sciences, Government Geologist, Department of Mines, Sydney. (President, 1921.)
1915		Armit, Henry William, M.R.C.S. *Eng.*, L.R.C.P. *Lond.*, The Printing House, Seamer-street, Glebe.
1919		Aurousseau, Marcel, B Sc., 9 Bannerman Street, Cremorne.
1923		Baccarini, Antonio, Doctor in Chemistry (Florence), 12 Roslyndale Avenue, Woollahra.
1878		Backhouse, His Honour Judge A. P., M.A., 'Melita,' Elizabeth Bay.
1924		Bailey, Victor Albert, M.A., D.Phil., F.Inst.P., Assoc -Professor of Physics in the University of Sydney.
1919		Baker, Henry Herbert, 15 Castlereagh-street.
1894	P 27	Baker, Richard Thomas, The Crescent, Cheltenham.
1894		‡Balsille, George, 'Lauderdale,' N.E. Valley, Dunedin, N.Z.
1926		Bannon, Joseph, Demonstrator in Physics in the University of Sydney; p.r. 'Dunisla,' The Crescent, Homebush.
1919		Bardsley, John Ralph, 'The Pines,' Lea Avenue, Five Dock.
1925		Barker-Woden, Lucien, F.R.G.S., "Wimbledon," Anderson-road, Double Bay.
1908	P 1	Barling, John, L.S., 'St. Adrians,' Raglan-street, Mosman.
1895	P 9	Barraclough, Sir Henry, K.B.E., B.E., M.M.E., M. Inst. C.E., M. I. Mech. E., Memb. Soc. Promotion Eng. Education; Memb. Internat. Assoc. Testing Materials; Dean of the Faculty of Engineering and Professor of Mechanical Engineering in the University of Sydney; p.r. 'Marmion,' Victoria-street, Lewisham.
1909	P 2	Benson, William Noel, D.Sc. *Syd.*, B.A. *Cantab.*, F.G.S., Professor of Geology in the University of Otago, Dunedin, N.Z.
1926		Bentivoglio, Sydney Ernest, B Sc Agr., 70 Young-street, Annandale.
1923		Berry, Frederick John, F C.S., 'Roseneath,' 51 Reynolds-street, Neutral Bay.
1919		Bettley-Cooke, Hubert Vernon, 'The Hollies,' Minter-street, Canterbury.

Elected.		
1923		Birks, George Frederick, c/o Potter & Birks, 15 Grosvenor st
1916		Birrell, Septimus, c/o Margarine Co., Edinburgh Road, Marrickville.
1920		Bishop, Eldred George, 8 Belmont-road, Mosman
1915		Bishop, John, 24 Bond-street.
1913		Bishop, Joseph Eldred, Killarney-street, Mosman.
1923	P 3	Blakely, William Faris, 'Myola,' Florence-street, Hornsby.
1905		Blakemore, George Henry, Room 32, Third Floor, Commercial Bank Chambers, 273 George-street.
188[illegible]		‡Blaxland, Walter, F R C.S. *Eng.*, L R C P. *Lond.*, 'Inglewood,' Florida Road, Palm Beach, Sydney.
1898		Blomfield, Charles E., B.C.E. *Melb.*, 'Woombi,' Kangaroo Camp, Guyra.
1917		Bond, Robert Henry, 'Eastbourne,' 27 Cremorne-road, Cremorne Point.
1926	P 1	Booker, Frederick William, B Sc., 'Dunkeld,' Nicholson-street, Chatswood.
1920	P 4	Booth, Edgar Harold, M.C., B.Sc., F Inst.P., Lecturer and Demonstrator in Physics in the University of Sydney.
1922		Bradfield, John Job Crew, D Sc Eng, M E, M Inst C E, M Inst E Aust Chief Engineer, Metropolitan Railway Construction, Railway Department, Sydney.
1916		Bragg, James Wood, B.A., c/o Gibson, Battle &Co. Ltd.,Kent-st.
1926		Branch, Kenneth James F., 99 North Steyne, Manly.
1917		Breakwell, Ernest, B.A., B.Sc, Headmaster Agricultural School, Yanco
1891		Brennand, Henry J. W., B.A , M.D., Ch.M. *Syd.*, V.D., Surgeon Commander R.A.N. Ret., 223 Macquarie-street; p r. 73 Milsons Road, Cremorne.
1923		Brereton, Ernest Le Gay, B Sc, Lecturer and Demonstrator in Chemistry in the University of Sydney.
1919	P 1	Briggs, George Henry, B.Sc, Ph.D, Lecturer and Demonstrator in Physics in the University of Sydney.
1922		Brough, Patrick, M.A., B.Sc., B Sc, (Agr.) (Glasgow), Lecturer in Botany in the University of Sydney.
1923		Brown, Herbert, 'Sikoti,' Alexander-street, Collaroy Beach, Sydney.
1906		Brown, James B., Resident Master, Technical School, Granville; p.r. 'Aberdour,' Daniel-street, Granville.
1913	P 12	Browne, William Rowan, D.Sc, Assistant-Professor of Geology in the University of Sydney.
1898		‡Burfitt, W. Fitzmaurice, B A , M.B., Ch M. B.Sc, *Syd.*, 'Wyoming,' 175 Macquarie-street, Sydney.
1926		Burkitt, Arthur Neville St George, M.B , B Sc., Professor of Anatomy in the University of Sydney.
1919	P 10	Burrows, George Joseph, B.Sc., Lecturer and Demonstrator in Chemistry in the University of Sydney; p.r. Watson-street, Neutral Bay.
1909		Calvert, Thomas Copley, Assoc M Inst.C.E., Department of Public Works, Sydney.
1904	P 27	Cambage, Richard Hind, C.B.E., L.S., F L.S., [illegible] Park Road, Burwood. (President 1912, 1923). *Hon. Secretary.*
1923		Cameron, Lindsay Duncan, Hilly-street, Mortlake.
1907		Campbell, Alfred W., M.D., Ch M. *Edin.*, 183 Macquarie-street.

Elected		
1876		Cape, Alfred J., M.A. *Syd.*, 'Karoola,' Edgecliff Road, Edgecliff.
1891		Carment, David, F.I.A. *Grt. Brit. & Irel.* F.F.A., *Scot.*, 4 Whaling Road, North Sydney.
1920		Carruthers, Sir Joseph Hector, K.C.M.G., M.L.C., M.A., *Syd.*, LL.D., *St. Andrews*, 'Highbury,' Waverley.
1903	P 3	Carslaw, Horatio S., M.A., Sc.D., Professor of Mathematics in the University of Sydney.
1913	P 3	Challinor, Richard Westman, F.I.C., F.C.S., Lecturer in Chemistry, Sydney Technical College.
1909	P 2	Chapman, Henry G., M.D., B.S., Professor of Physiology in the University of Sydney. *Hon. Treasurer.*
1913	P 15	Cheel, Edwin, Curator National Herbarium, Botanic Gardens, Sydney.
1925		Clark, William E., 'Acacia,' Cambridge-street, Epping.
1909	P 20	Cleland, John Burton, M.D., Ch.M., Professor of Pathology in the University of Adelaide. (President 1917.)
1876		Codrington, John Frederick, M.R.C.S. *Eng.*, L.R.C.P. *Lond.* and *Edin.*, 'Roseneath,' 8 Wallis-street, Woollahra.
1896	P 4	Cook, W. E., M.C.E. *Melb.*, M.Inst.C.E., Burroway-st., Neutral Bay.
1920		Cooke, Frederick, c/o Meggitt's Limited, 26 King-street.
1913	P 3	Coombs, F. A., F.C.S., Instructor of Leather Dressing and Tanning, Sydney Technical College; p.r. Bannerman Crescent, Rosebery.
1882		Cornwell, Samuel, J.P., 'Capanesk,' Tyagarah, North Coast.
1919		Cotton, Frank Stanley, B.Sc., Chief Lecturer and Demonstrator in Physiology in the University of Sydney.
1909	P 6	Cotton, Leo Arthur, M.A., D.Sc., Professor of Geology in the University of Sydney.
1892	P 1	Cowdery, George R., Assoc.M.Inst.C.E., 'Glencoe,' Torrington Road, Strathfield.
1886		Crago, W. H., M.R.C.S. *Eng.*, L.R.C.P. *Lond.*, 185 Macquarie-st.
1921		‡Cresswick, John Arthur, 101 Villiers-street, Rockdale.
1927	P 1	Currey, Geoffrey Saunders, 13 Princess-avenue, Homebush.
1925		Curry, Harris Eric Marshall, 8 Lower Wycombe Road, Neutral Bay.
1912		Curtis, Louis Albert, L.S., F.I.S. (N.S.W.), V.D., Office 207, 67 Castlereagh-street; p.r. No. 1 Mayfair Flats, Macleay-street, Darlinghurst.
1890		Dare, Henry Harvey, M.E., M.Inst.C.E., Commissioner, Water Conservation and Irrigation Commission, Union House, George-street.
1876	P 3	Darley, Cecil West, I.S.O., M.Inst.C.E., 'Longheath,' Little Bookham, Surrey, England; Australian Club, Sydney.
1886	P 23	David, Sir Edgeworth, K.B.E., C.M.G., D.S.O., B.A., D.Sc., F.R.S., F.G.S., Wollaston Medallist, Emeritus Professor of Geology and Physical Geography in the University of Sydney; p.r. 'Coringah,' Sherbroke-road, Hornsby. (President 1895, 1910.)
1919	P 2	de Beuzeville, Wilfrid Alex. Watt, Forestry Assessor, Forest Office, Tumut.
1921		Delprat, Guillaume Daniel, C.B.E., 'Keynsham,' Mandeville Crescent, Toorak, Victoria.
1921		Denison, Sir Hugh Robert, K.B.E., 701 Culwulla Chambers, Castlereagh-street.
1894		Dick, James Adam, C.M.G., B.A. *Syd.*, M.D., Ch.M., F.R.C.S. *Edin.* 'Catfoss,' 59 Belmore Road, Randwick.

Elected		
1924		Dickinson, Reginald E., B.Sc., Eng. *Lond.*, A.M.I.C.E., Chief Mechanical Engineer's Office, N. S. Wales Railways, Wilson-street, Redfern
1906		Dixson, William, 'Merridong,' Gordon Road, Killara.
1913	P 3	Doherty, William M., F.I.C., F.C.S., Second Government Analyst, 'Jesmond,' George-street, Marrickville.
1908	P 6	Dun, William S., Palæontologist, Department of Mines, Sydney. (President 1918.)
1924		Dupain, George Zephirin, A.A.C.I., F.C.S., Dupain Institute of Physical Education, Daking House, Pitt-street, p.r. 'Symington,' Parramatta Road, Ashfield.
1924		Durham, Joseph, 120 Belmore Road, Randwick.
1923	P 2	Earl, John Campbell, B.Sc., Ph.D., Professor of Organic Chemistry in the University of Sydney.
1919		Earp, The Hon. George Frederick, O.B.E., M.L.C., Australia House, Carrington-street.
1924		Eastaugh, Frederick Alldis, A.R.S.M., F.I.C., Assistant-Professor in Chemistry, Assaying and Metallurgy in the University of Sydney.
1918		‡Elliott, Edward, c/o Reckitts' (Oversea) Ltd., Bourke-street, Redfern.
1916	P 2	Enright, Walter J., B.A., High-street, West Maitland, N.S.W.
1908		Esdaile, Edward William, 42 Hunter-street.
1896		Fairfax, Geoffrey E., *S. M. Herald* Office, Hunter-street.
1887		Faithfull, R. L., M.D., *New York*, L.R.C.P., L.S.A. *Lond.*, c/o Iceton, Faithfull and Maddocks, 25 O'Connell-street.
1921		Farnsworth, Henry Gordon, 'Rothsay,' 90 Alt-street, Ashfield.
1910		Farrell, John, A.T.C., *Syd.*, Riverina Flats, 265 Palmer-street, Sydney.
1909	P 7	Fawsitt, Charles Edward, D.Sc., Ph.D., Professor of Chemistry in the University of Sydney. (President 1919).
1922		Ferguson, Andrew, 9 Martin Place, Sydney.
1927		Finnemore, Horace, B.Sc., F.I.C., Lecturer in Pharmacy in the University of Sydney.
1923		Fiaschi, Piero, O.B.E., M.D. (Columbia Univ.), D.D.S. (New York) M.R.C.S. (Eng.), L.R.C.P. (Lond.), 178 Phillip-street.
1920		Fisk, Ernest Thomas, Wireless House, 97 Clarence-street.
1888		Fitzhardinge, His Honour Judge G. H., M.A. 'Red Hill,' Pennant Hills
1922		Fleming, Edward Patrick, Chief Civic Commissioner, Town Hall, Sydney
1879		‡Foreman, Joseph, M.R.C.S. *Eng.* L.R.C.P. *Edin.*, 'The Astor,' Macquarie-street.
1920		Fortescue, Albert John, 'Benambra,' Loftus-street, Arncliffe.
1905		Foy, Mark, c/o Hydro Office, 133a Pitt-street, Sydney.
1904		Fraser, James, C.M.G., M.Inst.C.E., Chief Commissioner for Railways, Bridge-street.
[illegible]		Friend, Norman Bartlett, 48 Pile-street, Dulwich Hill.

Elected		
1918		Gallagher, James Laurence, M.A. *Syd.*, 'Akaroa,' Ellesmere Avenue, Hunter's Hill.
1926		Gibson, Alexander James, M.E., M.Inst.C.E., M.I.E.Aust., 906 Culwulla Chambers, Castlereagh-street, Sydney.
1921		Godfrey, Gordon Hay, M.A., B.Sc., Lecturer in Physics in the Technical College, Sydney; p.r. 262 Johnston-street, Annandale.
1897		Gould, The Hon. Sir Albert John, K.B., V.D., 'Eynesbury,' Edgecliff.
1922	P 5	Grant, Robert, F.C.S., Department of Public Health, 93 Macquarie-street.
1916		Green, Victor Herbert, 19 Bligh-street.
1922	P 1	Greig, William Arthur, Mines Department, Sydney.
1927		Gunn, Reginald Montague Gairns, B.Sc., B.Sc.Agr., M.R.C.V.S., Lecturer in Veterinary Anatomy and Surgery in the University of Sydney
1923		Gurney, William Butler, Government Entomologist, Department of Agriculture, Sydney.
1919		Grutzmacher, Frederick Lyle, F.C.S., Church of England Grammar School, North Sydney.
1880	P 5	Halligan, Gerald H., L.S., F.G.S., 'Edgecombe,' Telegraph Road, Pymble.
1912		Hallmann, E. F., B.Sc., 72 John-street, Petersham.
1892		Halloran, Henry Ferdinand, L.S., 82 Pitt-street.
1919		Hambridge, Frank, Adelaide Steamship Co. Chambers, Bridge-street, Sydney.
1916	P 1	Hamilton, Arthur Andrew, 'The Ferns,' 17 Thomas-st., Ashfield
1912		Hamilton, Alexander G., 'Tanandra,' Hercules-st., Chatswood.
1887	P 8	Hamlet, William M., F.I.C., F.C.S., Member of the Society of Public Analysts; 'Glendowan,' Glenbrook, Blue Mountains. B.M.A. Building, 30 Elizabeth-st. (President 1899, 1908).
1909		Hammond, Walter L., B.Sc., High School, Bathurst.
1916		Hardy, Victor Lawson, 'Tiri Mona,' 11A Gordon-av., Randwick
1905	P 5	Harker, George, D.Sc., F.A.C.I., Chamber of Commerce Building, 35 William-street, Melbourne.
1918	P 1	Harper, Leslie F., F.G.S., Geological Surveyor, Department of Mines, Sydney
1923		Harrison, Travis Henry, Lecturer in Entomology and Botany at the Hawkesbury Agricultural College, Richmond.
1918		Hassan, Alex. Richard Roby, c/o W. Angliss & Co. Ppty. Ltd., 64 West Smithfield, London, E.C.
1916		Hay Dalrymple-, Richard T., L.S.; 45 Bay-street, Double Bay
1914		Hector, Alex. Burnet, "Druminard," Greenwich-road, Greenwich.
1916		Henderson, James, 'Dunsfold,' Clanalpine-street, Mosman.
1919		Henriques, Frederick Lester, 208 Clarence-street.
1919	P 2	Henry, Max, D.S.O., B.V.Sc., M.R.C.V.S., 'Coram Cottage,' Essex-street, Epping.
1884	P 1	Henson, Joshua B., Assoc.M.Inst.C.E., 28 Barton-street, Mayfield, Newcastle.
1918		Hindmarsh, Percival, M.A., B.Sc. (Agr.), Teachers' College, The University, Sydney; p.r. 'Lurnea,' Canberra Avenue, Greenwich.

Elected.		
1921	P 2	Hindmarsh, William Lloyd, B.V.Sc., M.R.C.V.S., D.V.H., District Veterinary Officer, Armidale.
1916		Hoggan, Henry James, A.M.I.M.E., A M.I E. (Aust.). Manchester Unity Chambers, 160 Castlereagh-street; p r. 'Lincluden,' Frederick-street, Rockdale.
1924		Holme, Ernest Rudolph, O.B.E., M.A., Professor of English Language in the University of Sydney.
1901		Holt, Thomas S, 'Amalfi,' Appian Way, Burwood.
1905	P 8	Hooper, George, F.T.C. *Syd.*, 'Nycumbene,' Nielson Park, Vaucluse.
1920		Hordern, Anthony, C.B E., 12 Spring-street, Sydney.
1919		Hoskins, Arthur Sidney. Eskroy Park, Bowenfels.
1919		Hoskins, Cecil Harold, Windarra, Bowenfels.
1919		Houston, Ralph Liddle, No. 1 Lincluden Gardens, Fairfax-rd., Double Bay.
1906		Howle, Walter Cresswell, L.S.A. *Lond.*, 215 Macquarie-street.
1918		Hudson, G. Inglis, J.P., F.C.S., 'Gudvangen,' Arden-st., Coogee.
1920		Hulle, Edward William, Commonwealth Bank of Australia.
1923	P 2	Hynes, Harold John, B.Sc., (Agr.), Walter and Eliza Hall Agricultural Research Fellow, Biological Branch, Department of Agriculture, Sydney.
1927		Inglis, William Keith, M.D., Ch M., Lecturer in Pathology in the University of Sydney; p.r. 84 Wolseley-street, Drummoyne.
1923		Ingram, William Wilson, M.C., M.D., Ch B., The University, Sydney.
1922		Jacobs, Ernest Godfried, 'Cambria,' 106 Bland-street, Ashfield.
1904		Jaquet, John Blockley, A.R.S.M., F.G.S., Chief Inspector of Mines, Department of Mines, Sydney.
1925		Jenkins, Charles Adrian, B.E., B Sc., 2 Ramsgate Avenue, Bondi Beach.
1917		Jenkins, Richard Ford, Engineer for Boring, Irrigation Commission, 6 Union-street, Mosman.
1918		John, Morgan Jones, M.I.Mech.E., A.M.I.E.E. *Lond.*, M.I.E. *Aust.*, M.I.M. *Aust.*, Atlas Building, 8 Spring-street; p.r. Olphert Avenue, Vaucluse.
1909	P 15	Johnston, Thomas Harvey, M.A., D.Sc., F.L.S., C.M.Z.S., Professor of Zoology in the University of Adelaide.
1924		Jones, Leo Joseph, Geological Surveyor, Department of Mines, Sydney.
1911		Julius, George A., B.Sc., M.E., M I.Mech E., Culwulla Chambers, Castlereagh-street, Sydney.
1924		Kenner, James, Ph D., D.Sc., F.R.S., Professor of Technological Chemistry in the University of Manchester.
1924		Kenny, Edward Joseph, Field Assistant, Department of Mines, Sydney; p r. 45 Robert-street, Marrickville.
1887		Kent, Harry C., M.A., F.R.I.B.A., Dibbs' Chambers, 58 Pitt-st.
1919	P [illegible]	Kesteven, Hereward Leighton, M.D., Ch M., D.Sc., Bulladelah, New South Wales.
[illegible]		King, Kelso, 14 Martin Place.

Elected		
1928		Kinghorn, James Roy, Australian Museum, Sydney.
1920		Kirchner, William John, B.Sc. "Wanawong," Thornleigh-road, Beecroft.
1919		Kirk, Robert Newby, 25 O'Connell-street.
1881	P 29	Knibbs, Sir George, Kt., C.M.G., Hon.F.S.S., F.R.A.S., L.S., Member Internat. Assoc. Testing Materials; Memb. Brit. Sc. Guild, 'Cooyal,' 27 Sunnyside Avenue, Camberwell, Victoria. (President 1898).
1877		Knox, Edward W., 'Rona,' Bellevue Hill, Double Bay.
1911	P 3	Laseron, Charles Francis, Technological Museum.
1924		Leech, Thomas David James, B.Sc., *Syd.*, 'Orontes,' Clarke-st., Granville.
1920		Le Souef, Albert Sherbourne, Taronga Park, Mosman.
1916		L'Estrange, Walter William, 7 Church-street, Ashfield.
1909		Leverrier, Frank, B.A., B.Sc., K.C., Wentworth Road, Vaucluse.
1883		Lingen, J. T., M.A. *Cantab.*, K.C., c/o Union Club, Bligh-st.
1906		Loney, Charles Augustus Luxton, M.Am.Soc.Refr.E., Equitable Building, George-street.
1924		Love, David Horace, Beauchamp Avenue, Chatswood.
1927		Love, William Henry, B.Sc., "Lumeah," 9 Miller-street, Haberfield.
1884		MacCormick, Sir Alexander, K.C.M.G., M.D., C.M. *Edin.*, M.R.C.S. *Eng.*, 185 Macquarie-street.
1887		MacCulloch, Stanhope H., M.B., Ch.M. *Edin.*, 26 College-street.
1923		Mackay, Iven Giffard, C.M.G., D.S.O., B.A., Student Adviser and Secretary of Appointments Board, The University, Sydney.
1921		McDonald, Alexander Hugh Earle, Superintendent of Agriculture, Department of Agriculture, Sydney.
1903		McDonald, Robert, J.P., L.S., Pastoral Chambers, O'Connell-st; p.r. 'Lowlands,' William-street, Double Bay.
1919		McGeachie, Duncan, M.I.M.E., M.I.E. (Aust.), M.I.M.M. (Aust.), 'Craig Royston,' Toronto, Lake Macquarie.
1906		McIntosh, Arthur Marshall, 'Moy Lodge,' Hill-st., Roseville.
1891	P 2	McKay, R. T., L.S., M.Inst.C.E., Commissioner, Sydney Harbour Trust, Circular Quay.
1880	P 9	McKinney, Hugh Giffin, M.E., Roy. Univ. *Irel.*, M.Inst.C.E., Sydney Safe Deposit, Paling's Buildings, Ash-street.
1922		McLuckie, John, M.A., B.Sc., (*Glasgow*), D.Sc., (*Syd.*), Assistant-Professor of Botany in the University of Sydney.
1927		McMaster, Frederick Duncan, "Dalkeith," Cassilis.
1916		McQuiggin, Harold G., M.B., Ch.M., B.Sc., Lecturer and Demonstrator in Physiology in the University of Sydney; p.r. 'Berolyn,' Beaufort-street, Croydon.
1909		Madsen, John Percival Vissing, D.Sc., B.E., Professor of Electrical Engineering in the University of Sydney.
1924		Mance, Frederick Stapleton Under Secretary for Mines, Mines Department Sydney; p.r. 'Binbah,' Lucretia Avenue, Longueville.
1880	P 1	Manfred, Edmund C., Montague-street, Goulburn.

Elected		
1920	P 1	Mann, Cecil William, Kent-street, Epping.
1920		Mann, James Elliott Furneaux, Barrister at Law, c/o H. Southerden, Esq., Box 1646 J J., G P.O., Sydney.
1908		Marshall, Frank, C.M.G., B.D.S., 151 Macquarie-street.
1914		Martin, A. H., Technical College, Sydney.
1926		Mathews, Hamilton Bartlett, B.A. *Syd.*, Surveyor General of N.S W, Department of Lands, Sydney.
1912		Meldrum, Henry John, B.A., B.Sc. 'Craig Roy,' Sydney Road, Manly.
1922		Mills, Arthur Edward, M.B., Ch M, Dean of the Faculty of Medicine, Professor of Medicine in the University of Sydney; p.r. "The Astor," Macquarie-street.
1926		Mitchell, Ernest Marklow, 106 Harrow Road, Rockdale
1879		Moore, Frederick H., Union Club, Sydney.
1922	P 11	Morrison, Frank Richard, Assistant Chemist, Technological Museum, Sydney; p.r. Brae-street, Waverley.
1924		Morrison, Malcolm, Department of Mines, Sydney.
1924		Mullens, Arthur Launcelot, c/o Mullens & Co, 115 Pitt-street.
1879		Mullins, John Lane, M.L.C., M.A. *Syd.*, 'Killountan,' Double Bay.
1915		Murphy, R K., Dr. Ing., Chem. Eng., Lecturer in Chemistry, Technical College, Sydney.
1923	P 2	Murray, Jack Keith, B.A., B.Sc (Agr.), Principal, Queensland Agricultural College, Gatton, Queensland.
1893	P 4	Nangle, James, O.B.E., F.R.A.S., Superintendent of Technical Education, The Technical College, Sydney; Government Astronomer, The Observatory, Sydney (President 1920. *Vice-President*.
1917		Nash, Norman C., 'Ruanora,' King's Road, Vaucluse.
1924		Nickoll, Harvey, L.R.C.P., L.R.C.S., Barham, via Mudgee, N.S.W.
1891		‡Noble, Edward George, L.S., 8 Louisa Road, Balmain.
1920		Noble, Robert Jackson, M.Sc., B.Sc Agr., Ph.D., Agricultural Museum, George-street, North; p r. 'Lyndon,' Carrington-street, Homebush.
1903		‡Old, Richard, 'Waverton,' Bay Road, North Sydney
1921		Olding, George Henry, 4 Bayswater Road, Drummoyne.
1913		Ollé, A. D., F.C.S., 'Kareema,' Charlotte-street, Ashfield.
1896		Onslow, Col. James William Macarthur, B.A., LL.B, 'Gilbulla,' Menangle.
1917		Ormsby, Irwin, 'Caleula,' Allison Road, Randwick.
1891		Osborn, A. F., Assoc M.Inst.C.E., Water Supply Branch, Sydney; p.r. 'Waugoola,' Fern-street, Pymble.
1921	P 2	Osborne, George Davenport, B.Sc, Lecturer and Demonstrator in Geology in the University of Sydney; p.r. 'Belle-Vue,' Kembla-st., Arncliffe.
1920		*Paine, William Horace, State Abattoirs, Homebush Bay, N.S.W.
1880		Palmer, Joseph, 96 Pitt-st.; p.r. Kenneth-st., Willoughby.

Elected		
1921		Parkes, Varney, Conjola, South Coast.
1920	P 44	Penfold, Arthur Ramon, F.C.S., Curator and Economic Chemist, Technological Museum, Harris-street, Ultimo.
1909	P 2	Pigot, Rev. Edward F., S.J., B.A., M.B. *Dub.*, Director of the Seismological Observatory, St. Ignatius' College, Riverview.
1879	P 8	Pittman, Edward F., Assoc R.S.M. L.S., 'The Oaks,' Park-street, South Yarra, Melbourne.
1881		Poate, Frederick, F.R.A.S., L.S., 'Clanfield,' 50 Penkivil-street, Bondi.
1919		Poate, Hugh Raymond Guy, M.B., Ch. M. *Syd.*, F.R.C.S. *Eng.*, L.R.C.P. *Lond.*, 225 Macquarie-street.
1917		Poole, William, M.E., (Civil, Min. and Met.) *Syd.*, M. Inst. C.E., M.I.M.M., M.I.E., Aust., M.Am I.M.E., M. Aust. I. M.M., L.S., 906 Culwulla Chambers, Castlereagh-street.
1896		Pope, Roland James, B.A., *Syd.*, M.D., Ch.M., F.R.C.S.. *Edin.*, 185 Macquarie-street.
1921	P 2	Powell, Charles Wilfrid Roberts, A.I.C., c/o Colonial Sugar Refining Co., O'Connell-street.
1918		Powell, John, 170-2 Palmer-street.
1927		Price, William Lindsay, B E., B.Sc., 63 Kareela-road, Cremorne.
1918		Priestley, Henry, M.D., Ch M., B.Sc, Associate-Professor of Physiology in the University of Sydney.
1893		Purser, Cecil, B.A., M.B., Ch M. *Syd.*, 185 Macquarie-street.
1912	P 2	Radcliff, Sidney, F.C.S., Department of Chemistry, The University of Sydney.
1927		Radcliffe-Brown, Alfred Reginald, M.A., *Cantab.*, M.A., *Adel.*, F.R.A.I, *Cantab.*, Professor of Anthropology in the University of Sydney.
1922		Raggatt, Harold George, B.Sc, "Meru," Epping-av., Epping.
1919	P 3	Ranclaud, Archibald Boscawen Boyd, B.Sc., B.E., Lecturer in Physics, Teachers' College, The University, Sydney.
1909		Reid, David, 'Holmsdale,' Pymble.
1920		Richardson, John James, A.M.I.E.E. *Lond.*, 'Kurrawyba,' Upper Spit Road, Mosman.
1924		Robertson, James R. M., M.D., C.M., F.R.G.S., F.G.S., 'Vanduara,' Ellamang Avenue, Kirribilli.
1884		Ross, Chisholm, M.D. *Syd.*, M.B., Ch.M., *Edin.*, 225 Macquarie-st.
1895	P 1	Ross, Herbert E., Equitable Building, George-street.
1927		Ross, Ian Clunies, B V.Sc., "Lorne," The Grove, Woollahra.
1925		Roughley, Theodore Cleveland, Technological Museum, Sydney.
1897		Russell, Harry Ambrose, B.A., c/o Sly and Russell, 369 George-street; p.r. 'Mahuru,' Park Road, Bowral.
1907		Ryder, Charles Dudley, Assoc.I.E.M., F.C.S., A.A.C.I., Sydney-st., Chatswood.
1922		Sandy, Harold Arthur Montague, 326 George-street.
1926		Saunderson, William. B.Sc. *Dun.*, F.C.S., Licentiate, College of Preceptors *England*, c/o Imperial Service Club, 12 O'Connell-street, Sydney.

Elected		
1917		Sawkins, Dansie T., M.A., 'Brymedura,' Kissing Point Road, Turramurra.
1920		Sawyer, Basil, B.E. 'Birri Birra,' The Crescent, Vaucluse.
1920		Scammell, Rupert Boswood, B.Sc., *Syd.*, 18 Middle Head Road, Mosman.
1918		Scammell, W. J., Mem. Pharm. Soc. *Grt. Brit.*, 18 Middle Head Road, Mosman.
1919		Sear, Walter George Lane, c/o J. Kitchen & Sons, Ingles-st., Port Melbourne.
1923	P 1	Seddon, Herbert Robert, D.V.Sc., Director, Veterinary Research Station, Glenfield.
1918		Sevier, Harry Brown, c/o Lewis Berger and Sons (Aust.) Ltd., Cathcart House, Castlereagh-street.
1924		Shelton, James Peel, M.Sc., B.Sc., Agr., Department of Agriculture, Canberra.
1927		Shearsby, Alfred James, 152 Bland-street, Haberfield.
1917		Sibley, Samuel Edward, Mount-street, Coogee.
1900		‡Simpson, R. C., Lecturer in Electrical Engineering, Technical College, Sydney.
1910		Simpson, William Walker, 'Strathford,' Lord-street, Roseville.
1916		Smith, Stephen Henry, Under Secretary and Director of Education, Department of Education, Sydney.
1922	P 1	Smith, Thomas Hodge, Australian Museum, Sydney.
1919		Southee, Ethelbert Ambrook, O.B.E., M.A., B.Sc., Principal, Hawkesbury Agricultural College, Richmond, N.S.W.
1921		Spencer-Watts, Arthur, 'Araboonoo,' Glebe-street, Randwick.
1917		Spruson, Wilfred Joseph, Daily Telegraph Building, King-st.
1916		Stephen, Alfred Ernest, F.C.S., Box 1197 H.H.G.P.O., Sydney.
1921		Stephen, Henry Montague. B.A., LL.B., c/o McCarthy & Marshall, 11A Castlereagh-street.
1914		Stephens, Frederick G. N., F.R.C.S., M.B., Ch.M., 13 Dover Road, Rose Bay.
1920	P 1	Stephens, John Gower, M.B., Royal Prince Alfred Hospital, Camperdown.
1913		Stewart, Alex. Hay, B.E., 'Yunah,' 22 Murray-street, Croydon
1900		Stewart, J. Douglas, B.V.Sc., M.R.C.V.S., Professor of Veterinary Science in the University of Sydney; p.r. 'Berelle,' Homebush Road, Strathfield. *President.*
1909		Stokes, Edward Sutherland, M.B. *Syd.*, F.R.C.P. *Irel.*, Medical Officer, Metropolitan Board of Water Supply and Sewerage, 341 Pitt-street.
1916	P 1	Stone, W. G., Assistant Analyst, Department of Mines, Sydney.
1927		Stump, Claude Witherington, M.D., D.Sc., Assoc.-Professor of Anatomy in the University of Sydney, p.r. 40 Shirley-rd. Wollstonecraft.
1919		Stroud, Sydney Hartnett, F.I.C., Ph.C., c/o Elliott Bros., Ltd., Terry-street, Rozelle.
1918		Sullivan, Herbert Jay, c/o Lewis Berger and Sons (Aust.) Ltd., Rhodes.
1920		Sulman, Sir John, Kt., Warrung-st., McMahon's Point, North Sydney.
1918		Sundstrom, Carl Gustaf, c/o Federal Match Co., Park Road, Alexandria.
1901	P 11	‡Sussmilch, C. A., F.G.S., Principal of the East Sydney Technical College, and Assistant Superintendent of Technical Education. (President 1922.) *Vice-President.*

Elected		
1919		‡Sutherland, George Fife, A.R.C.Sc. *Lond.*, Assistant-Professor in Mechanical Engineering, in the University of Sydney.
1920		Sutton, Harvey, O.B.E., M.D., D.P.H. *Melb.*, B.Sc. *Oxon.*, 'Lynton,' Kent Road, Rose Bay.
1919		Swain, Herbert John, B.A. *Cantab.*, B.Sc., B.E. *Syd.*, Lecturer in Mechanical Engineering, Technical College, Sydney.
1926		Tannahill, Robert William, B.Sc. *Syd.*, 'Astoria,' Kirribilli
1915	P 3	Taylor, Harold B., D.Sc., Kenneth-street, Longueville.
1921	P 2	Taylor, John Kingsley, Hawkesbury Agricultural College, Richmond; p.r. 16 Ferrier-street, Rockdale.
1905		‡Taylor, John M., M.A., LL.B. *Syd.*, 'Woonona,' 43 East Crescent-street, McMahon's Point, North Sydney.
1921	P 4	Taylor, Thomas Griffith, B.A., D.Sc., B.E., Associate-Professor of Geography in the University of Sydney.
1899		Teece, R., F.I.A., F.F.A., Wolseley Road, Point Piper.
1923		Thomas, David, B.E., M.I.M.M., F.G.S., 15 Clifton Avenue, Burwood.
1919		Thomas, John, L.S., 'Remeura,' Pine and Harrow Roads, Auburn.
1924		Thompson, Herbert William, 'Marathon,' Francis-st., Randwick
1913		Thompson, Joseph, M.A., LL.B., Vickery's Chambers, 82 Pitt-st.
1919		Thorne, Harold Henry, B.A. *Cantab.*, B.Sc. *Syd.*, Lecturer in Mathematics in the University of Sydney; p.r. Rutledge-st., Eastwood.
1916		Tillyard, Robin John, M.A., D.Sc., F.R.S., F.L.S., F.E.S., *Director* of Entomological Research, Canberra.
1923		Timcke, Edward Waldemar, Meteorologist, Weather Bureau, Sydney.
1923		Tindale, Harold, Works Engineer, c/o Australian Gas-Light Co., Mortlake.
1923		Toppin, Richmond Douglas, A.I.C., Parke Davis & Co., Rosebery.
1879		Trebeck, P. C., "Boera," Queen-street, Bowral.
1925		Tye, Cyrus Willmott Oberon, Under Secretary for Public Works, Public Works Dept., Sydney; p.r. 19 Muston-st., Mosman.
1916		Valder, George, J.P., 3 Milner-street, Mosman.
1890		Vicars, James, M.E., Memb. Intern. Assoc. Testing Materials; Memb. B. S. Guild; Challis House, Martin Place.
1921		Vicars, Robert, Marrickville Woollen Mills, Marrickville.
1892		Vickery, George B., 78 Pitt-street.
1903	P 5	Vonwiller, Oscar U., B.Sc., F.Inst.P., Professor of Physics in the University of Sydney. *Hon. Secretary.*
1924		Wade, Rev. Robert Thompson, M.A., Headfort School, Killara
1919		Waley, Robert George Kinloch, 63 Pitt-street.
1910		Walker, Charles, 'Lynwood,' Terry Road, Ryde.

Elected		
1910		Walker, Harold Hutchison, Vickery's Chambers, 82 Pitt-st.
1879		Walker, H. O., 'Moora,' Crown-street, Parramatta.
1919	P 1	Walkom, Arthur Bache, D.Sc., Macleay House, 16 College-st.
1903		Walsh, Fred., J.P., Consul-General for Honduras in Australia and New Zealand; For. Memb. Inst. Patent Agents, London; Patent Attorney Regd. U.S.A.; Memb Patent Law Assoc., Washington; Regd. Patent Attorn. Comm. of Aust; Memb. Patent Attorney Exam. Board Aust; George and Wynyard-streets; p.r. 'Walsholme,' Centennial Park, Syd.
1901		Walton, R H., F C.S., 'Flinders,' Martin's Avenue, Bondi.
1918		Ward, Edward Naunton, Curator of the Botanic Gardens, Syd.
1913	P 4	Wardlaw, Hy. Sloane Halcro, D.Sc. *Syd.*, Lecturer and Demonstrator in Physiology in the University of Sydney.
1922		Wark, Blair Anderson, V.C., D.S.O., M.I.Q.C., c/o Thompson and Wark, T. & G Building, Elizabeth-street; p.r. 'Braeside,' Zeta-street, Lane Cove, Sydney.
1921		‡Waterhouse, G. Athol, D.Sc, B.E., F.E.S., Stanhope Road, Killara.
1924		Waterhouse, Leslie Vickery, B.E. *Syd*, 6th Floor, Wingello House, Angel Place, Sydney.
1919		Waterhouse, Lionel Lawry, B.E. *Syd*, Lecturer and Demonstrator in Geology in the University of Sydney.
1919	P 3	Waterhouse, Walter L., M.C., B.Sc Agr., D I.C., 'Hazelmere,' Chelmsford Avenue, Roseville.
1919		Watkin-Brown, Willie Thomas, F.R.M.S., Lucasville Road, Glenbrook
1876		Watkins, John Leo, B.A. *Cantab.*, M.A. *Syd.*, University Club, Castlereagh-street
1910		Watson, James Frederick, M.B., Ch M., 'Midhurst,' Woollahra.
1911	P 1	Watt, Robert Dickie, M.A., B.Sc., Professor of Agriculture in the University of Sydney. (President, 1925).
1920	P 20	Welch, Marcus Baldwin, B.Sc, A.I.C., Economic Botanist, Technological Museum.
1920	P 1	Wellish, Edward Montague, M.A., Associate-Professor in Mathematics in the University of Sydney.
1921		Wenholz, Harold, Director of Plant Breeding, Department of Agriculture, Sydney.
1881		‡Wesley, W. H, London.
1922		Whibley, Harry Clement, 39 Moore-street, Leichhardt.
1909	P 3	‡White, Charles Josiah, B.Sc., Lecturer in Chemistry, Teacher's College.
1918		White, Edmond Aunger, M.A.I.M.E., c/o Electrolytic Refining and Smelting Co. of Australia Ltd., Port Kembla, N.S.W.
1892	P 1	White, Harold Pogson, F.C.S., Assayer and Analyst, Department of Mines; p r. 'Quantox,' Park Road, Auburn.
1923		Whitehouse, Frank, B.V.Sc, (Syd.) 'Dane Bank,' Albyn Road, Strathfield.
1927		Wilkinson, Herbert John, B.A., M.B, Ch.M., Senior Lecturer and Demonstrator in Anatomy in the University of Sydney, p.r. 53 Liverpool Road, Summer Hill.
1921		Willan, Thomas Lindsay, B Sc., c/o Alluvial Tin Malaya Ltd., Ho Hong Bank Bld., Market and Beach Streets, Penang, Straits Settlements.
1920		Williams, Harry, A.I.C., c/o Whiddon Bros.' Rosebery Lanolines Pty. Ltd, Arlington Mills, Botany.

Elected		
1924		Williams, William John, 5 Effingham-street, Mosman.
1917		Willington, William Thos., O.B.E., 33 Willington-st., Arncliffe.
1923		Wilson, Stanley Eric, 'Chatham,' James-street, Manly.
1891		Wood, Percy Moore, L.R.C.P. *Lond*, M.R.C.S. *Eng.*, 'Redcliffe,' Liverpool Road, Ashfield.
1906	P 11	Woolnough, Walter George, D.Sc., F.G.S., 'Callabonna,' Park Avenue, Gordon. (President, 1926) *Vice-President.*
1916		Wright, George, c/o Farmer & Company, Pitt-street.
1917		Wright, Gilbert, Lecturer and Demonstrator in Agricultural Chemistry in the University of Sydney.
1921		Yates, Guy Carrington, 184 Sussex-street.

Honorary Members.

Limited to Twenty.

M.—Recipients of the Clarke Medal.

1918		Chilton, Charles, M.A., D.Sc., M.B., C.M. etc., Professor of Biology, Canterbury College, Christchurch, N.Z.
1914		Hill, James P., D.Sc., F.R.S., Professor of Zoology, University College, London.
1908		Kennedy, Sir Alex. B. W., Kt., LL.D., D. Eng., F.R.S., Emeritus Professor of Engineering in University College, London, 17 Victoria-street, Westminster, London S.W.
1915		Maitland, Andrew Gibb, F.G.S., Government Geologist of Western Australia, 'Bon Accord,' 2 Charles-street, South Perth, W.A.
1912		Martin, C. J., C.M.G., D.Sc., F.R.S., Director of the Lister Institute of Preventive Medicine, Chelsea Gardens, Chelsea Bridge Road, London, S.W. 1.
1894	M	Spencer, Sir W. Baldwin, K.C.M.G., M.A., D.Sc., F.R.S., Emeritus Professor of Biology in the University of Melbourne, National Museum Melbourne.
1900	M	Thiselton-Dyer, Sir William Turner, K.C.M.G., C.I.E., M.A., LL.D., Sc.D., F.R.S., The Ferns, Witcombe, Gloucester, England.
1915		Thomson, Sir J. J., O.M., D.Sc., F.R.S., Nobel Laureate, Master of Trinity College, Cambridge, England.
1921		Threlfall, Sir Richard, C.B.E., M.A., F.R.S., lately Professor of Physics in the University of Sydney, 'Oakhurst, Church Road, Edgbaston, Birmingham, England.
1922		Wilson, James T., M.B., Ch.M. *Edin.*, F.R.S., Professor of Anatomy in the University of Cambridge, England. 81 Grange Road, Cambridge, England.

Obituary 1927-28.

Ordinary Members.

Elected.		Elected.	
1918	Barr, Robert Houston	1872	Liversidge, Archibald
1876	Brady, Andrew John	1878	MacDonald, Ebenezer
1920	Ferguson, Eustace William	1925	Taylor, George Augustine
1899	Greig-Smith, Robert	1893	Taylor, James
1918	Harrison, Launcelot	1907	Welch, William
1876	Keele, Thomas William		

AWARDS OF THE CLARKE MEDAL.

Established in memory of

The Revd. WILLIAM BRANWHITE CLARKE, M.A., F.R.S., F.G.S., etc.

Vice-President from 1866 *to* 1878.

To be awarded from time to time for meritorious contributions to the Geology, Mineralogy, or Natural History of Australia. The prefix * indicates the decease of the recipient.

Awarded

1878 *Professor Sir Richard Owen, K.C.B., F.R.S.
1879 *George Bentham, C.M.G., F.R.S.
1880 *Professor Thos Huxley, F.R.S.
1881 *Professor F. M'Coy, F.R.S., F.G.S.
1882 *Professor James Dwight Dana, LL.D.
1883 *Baron Ferdinand von Mueller, K.C.M.G., M.D., Ph.D., F.R.S., F.L.S.
1884 *Alfred R. C. Selwyn, LL.D., F.R.S., F.G.S.
1885 *Sir Joseph Dalton Hooker, O.M., G.C.S.I., C.B., M.D., D.C.L., LL.D., F.R.S.
1886 *Professor L. G. De Koninck, M.D.
1887 *Sir James Hector, K.C.M.G., M.D., F.R.S.
1888 *Rev. Julian E. Tenison-Woods, F.G.S., F.L.S.
1889 *Robert Lewis John Ellery, F.R.S., F.R.A.S.
1890 *George Bennett, M.D., F.R.C.S. *Eng.*, F.L.S., F.Z.S.
1891 *Captain Frederick Wollaston Hutton, F.R.S., F.G.S.
1892 Sir William Turner Thiselton Dyer, K.C.M.G., C.I.E., M.A., LL.D., Sc.D., F.R.S., F.L.S., late Director, Royal Gardens, Kew.
1893 *Professor Ralph Tate, F.L.S., F.G.S.
1895 *Robert Logan Jack, LL.D., F.G.S., F.R.G.S.
1895 *Robert Etheridge, Jnr.
1896 *The Hon. Augustus Charles Gregory, C.M.G., F.R.G.S.
1900 *Sir John Murray, K.C.B., LL.D., Sc.D., F.R.S.
1901 *Edward John Eyre.
1902 *F. Manson Bailey, C.M.G., F.L.S.
1903 *Alfred William Howitt, D.Sc., F.G.S.
1907 Walter Howchin, F.G.S., University of Adelaide.
1909 Dr. Walter E. Roth, B.A., Pomeroon River, British Guiana, South America.
1912 *W. H. Twelvetrees, F.G.S.
1914 A. Smith Woodward, LL.D., F.R.S., Keeper of Geology, British Museum (Natural History) London.
1915 *Professor W. A. Haswell, M.A., D.Sc., F.R.S.
1917 Professor Sir Edgeworth David, K.B.E., C.M.G., D.S.O., B.A., D.Sc., F.R.S., F.G.S., The University, Sydney.
1918 Leonard Rodway, C.M.G., Honorary Government Botanist, Hobart, Tasmania.
1920 *Joseph Edmund Carne, F.G.S.
1921 *Joseph James Fletcher, M.A., B.Sc.,
1922 Richard Thomas Baker, The Avenue, Cheltenham.
1923 Sir W. Baldwin Spencer, K.C.M.G., M.A., D.Sc., F.R.S., National Museum, Melbourne
1924 *Joseph Henry Maiden, I.S.O., F.R.S., F.L.S., J.P.
1925 *Charles Hedley, F.L.S.
1927 Andrew Gibb Maitland, F.G.S., "Bon Accord," Melville Place, South Perth.

AWARDS OF THE SOCIETY'S MEDAL AND MONEY PRIZE.

Money Prize of £25.

Awarded.

1882 John Fraser, B.A., West Maitland, for paper entitled 'The Aborigines of New South Wales.'

1882 Andrew Ross, M.D., Molong, for paper entitled 'Influence of the Australian climate and pastures upon the growth of wool.'

The Society's Bronze Medal and £25.

1884 W. E. Abbott, Wingen, for paper entitled 'Water supply in the Interior of New South Wales.'

1886 S. H. Cox, F.G.S., F.C.S., Sydney, for paper entitled 'The Tin deposits of New South Wales.'

1887 Jonathan Seaver, F.G.S., Sydney, for paper entitled 'Origin and mode of occurrence of gold-bearing veins and of the associated Minerals.'

1888 Rev. J. E. Tenison-Woods, F.G.S., F.L.S., Sydney, for paper entitled 'The Anatomy and Life-history of Mollusca peculiar to Australia'

1889 Thomas Whitelegge, F.R.M.S., Sydney, for paper entitled 'List of the Marine and Fresh-water Invertebrate Fauna of Port Jackson and Neighbourhood.'

1889 Rev. John Mathew, M.A., Coburg, Victoria, for paper entitled 'The Australian Aborigines.'

1891 Rev. J. Milne Curran, F.G.S., Sydney, for paper entitled 'The Microscopic Structure of Australian Rocks.'

1892 Alexander G. Hamilton, Public School, Mount Kembla, for paper entitled 'The effect which settlement in Australia has produced upon Indigenous Vegetation.'

1894 J. V. De Coque, Sydney, for paper entitled the 'Timbers of New South Wales.'

1894 R. H. Mathews, L.S., Parramatta, for paper entitled 'The Aboriginal Rock Carvings and Paintings in New South Wales.'

1895 C. J. Martin, D.Sc., M.B., F.R.S., Sydney, for paper entitled 'The physiological action of the venom of the Australian black snake (*Pseudechis porphyriacus*).'

1896 Rev. J. Milne Curran, Sydney, for paper entitled 'The occurrence of Precious Stones in New South Wales, with a description of the Deposits in which they are found.'

PRESIDENTIAL ADDRESS

By W. G. Woolnough, D.Sc., F.G.S.

Delivered to the Royal Society of New South Wales on May 4, 1927

The past year has been one of considerable scientific activity. The two most outstanding events have been the 18th meeting of the Australasian Association for the Advancement of Science and the third meeting of the Pan-Pacific Science Congress.

For the first time in its history the Australasian Association met in Perth. It will be remembered that an invitation was received in 1913 for a meeting to be held in Western Australia. The intervention of the war delayed matters, and the project was realised ten years later. It was an undertaking of considerable magnitude to transport a contingent of some 220 visitors right across the continent, but the task was very satisfactorily accomplished by the various railways concerned. The Commonwealth Government assisted very materially by providing a substantial grant as a contribution towards the travelling expenses.

In Western Australia, lavish hospitality was forthcoming, as those who knew the State fully expected. The State Government also contributed towards the cost of printing the volume of proceedings, and towards the travelling expenses connected with the excursions.

The meetings were well attended, and the papers were of a high order of merit. Joint discussions between several sections were a feature of the meeting. Such interchanges of views between specialists along different lines cannot fail to be of enormous value, and must make for better

feeling, and for better mutual understanding of border-line problems. An *innovation* was the holding of a number of evening sessions, an experiment the success of which will probably lead to its repetition. The excursions were an outstanding feature of the meeting, and visitors had unique opportunities of realising that, in many respects, Western Australia is structurally and biologically quite as sharply marked off from the rest of Australia as if a thousand miles of ocean rolled between.

Immediately after the close of this highly successful meeting it was necessary for the scientific delegates to the Pan-Pacific Science Congress to start for Japan.

The Third Pan-Pacific Science Congress was held in Tokio, Japan, in October and November, 1926, under the auspices of the National Research Council of Japan and was attended by upwards of 130 delegates from overseas. The countries represented were those bordering or having interest in the Pacific and included the United States of America, Australia, Canada, France, Great Britain, Hawaii, Japan, Netherlands, Netherlands East Indies, New Zealand, Philippine Islands, and for the first time, China and Russia.

The subjects discussed at the Congress included all branches of physical and biological Sciences and a very full programme was carried out.

At this meeting a Pacific Science Association was formed and a constitution adopted under which future Pacific Science Congresses will be held at intervals of not less than two years nor more than five years. The prefix "Pan" has been dispensed with. The next meeting is to be held in Java in 1929.

The Commonwealth Government was represented by Sir Hubert Murray, K.C.M.G., Lieut.-Governor of Papua, and the following three members of this Society: Mr. R. H.

Cambage, C.B.E., *President of the Australian National Research Council;* Mr. E. C. Andrews and the Rev. E. F. Pigot. Other members of the Society who attended were: Professors L. A. Cotton, T. Griffith Taylor, O. U. Vonwiller and W. N. Benson (New Zealand), also Mr. G. H. Halligan.

After a very strenuous, but highly successful campaign, the public appeal for the raising of a sum of £100,000 for cancer research was brought to a conclusion last year. The sum aimed at was much over-subscribed, and the Governments of the Commonwealth and States added their quota. As a result, we are able, in Australia, to take our place worthily in the ranks of the nations in their fight against the awful scourge of cancer. It is certain that success must be attained, and that it must be attained purely by scientific research, and we, as men of science, must and will do all in our power to assist the investigation.

Laboratory accommodation has been provided by the University of Sydney, and a highly efficient, and, *mirabile dictu,* an adequately paid scientific staff is being got together. May we not confidently hope that *our* Cancer Research Institute will give a good account of itself, and contribute worthily to the eventual solution of this most pressing problem?

Honours have been conferred on some of our veteran members during the year.

At a meeting of the Executive Committee of the Australian National Research Council held in Melbourne, Mr. R. H. Cambage, C.B.E., F.L.S., the Nestor of our Society, was elected as President. While this promotion means that the Council loses a prince among secretaries, we feel that it gains by having Mr. Cambage as its President. Mr. Cambage was also elected President of the Australasian Association for the Advancement of Science —the "blue ribbon" of Australasian Science.

Professor R. D. Watt, M.A., B.Sc., was elected Chairman of the State Advisory Committee of the Council for Scientific and Industrial Research.

Mr. E. C. Andrews, Government Geologist of New South Wales, has been invited to deliver the Silliman Foundation Lectures at the Yale University in 1927. The Silliman Lecturer is always a man of great scientific eminence, and the selection of Mr. Andrews as a member of this distinguished band is not only a very great personal honour, but reflects lustre upon this State and its scientific activities.

Sir Alexander MacCormick was invested with the insignia of a Knight Commander of the Most Distinguished Order of St. Michael and St. George by His Excellency the Governor-General.

Dr. A. B. Walkom, Secretary of the Linnean Society of New South Wales, was awarded a Fellowship in science by the International Education Board, New York, to enable him to study for one year at the University of Cambridge.

The medal of the Society of Artists "in appreciation of good service for the advancement of Australian art" was presented, in October last, to Sir Baldwin Spencer.

This year, the Clarke Memorial Medal, the most important gift at the disposal of this Society, has been awarded to Andrew Gibb Maitland, F.G.S., who retired recently from the position of Government Geologist of Western Australia, a position which he had filled for many years.

In his younger days Mr. Maitland did very valuable geological work in Queensland and New Guinea, under conditions of great difficulty and often of great danger.

His personal researches in Western Australia have extended over almost the whole of that enormous State,

and have added very greatly to our knowledge of its very complicated structure. As head of the Survey he organised and directed a service which has played its part most worthily in all fields of geological and mineralogical research. Almost ultra-conscientious and extremely cautious in arriving at conclusions, Mr. Maitland's geological work bears the stamp of absolute thoroughness, and his name will occupy no insignificant place in the long list of distinguished scientists who have been awarded the Clarke Memorial Medal.

The Society's work during the past year has followed the usual lines. Twenty-seven papers have been read at our meetings, representing a fair average quantity and quality of scientific work. The attendance at our monthly meetings is small, and activity of discussion is at a low ebb. This state of affairs is by no means peculiar to our Society, nor to this city or State. I have been informed by persons who have recently returned from abroad that similar conditions prevail in the leading scientific societies of other countries.

The cause is not far to seek. Half a century ago scientific societies were not numerous, and all who were interested in scientific work gathered together to discuss it. Moreover, science had not reached the degree of specialisation it has attained to-day. There were more "naturalists" and fewer "ologists." Everybody knew sufficient of a subject to be intelligently interested, and most knew enough (or thought they did) to enable them to participate in discussions.

The multiplication of special societies and sections has tended, more and more, to rob the general societies of their membership, or rather, of attendants at their general meetings. The specialist naturally prefers to spend the small amount of time he can spare for evening meetings

in company with a select group of his peers, with whom he can discuss the most intricate parts of his subject, without the severe restriction imposed by the necessity of making his language intelligible to an audience of laymen. This tendency *must* grow with the ever-increasing specialisation in science. That our Society recognises this is shown by the number and activity of its sections. It does, however, seem a pity that the growth of the children should, of necessity, involve the starvation of the parent. Is such a result either necessary or desirable? Is it inevitable that specialisation must be carried to the point when a physicist and a botanist can no longer understand one another at all? Surely an occasional interchange of views must do good. One must sympathise with the feelings of the physicist condemned to listen to a technical botanical paper read *in extenso*, or even in abstract; and equally so for a botanist when the physicist has the floor; while the state of both when a mere geologist holds forth, is better imagined than described.

I do not wish for a moment to suggest that the presentation of original papers at our meetings is undesirable. We exist for the purpose of receiving and publishing the results of original work, and this object must always remain our principal aim. At the same time, is it not possible to make the general meetings a sort of clearing house for the mutual exchange of scientific knowledge, and, in some degree, to counteract the evils of over-specialisation? I would not have our meetings degenerate into mere conversaziones; still less do I desire them to take on the smoke-laden atmosphere of a social club. Any man who cannot put aside his pipe for an hour to take part in a well-planned scientific discussion is the slave of an evil habit. I am sure that something may be done to promote greater interest and wider mutual understanding and appreciation.

From the privileged security of the Chair I venture to make the following suggestions:

(1). Let all purely technical papers be taken as read. This will give them the desired status as regards priority of publication. When they appear in print, even in the stage of galley proof, they can be submitted to the members interested. They can then be discussed, in full detail, at the appropriate section, where they will create enthusiasm in place of ennui, and where the most ardent smoker can indulge his tastes to the full.

(2). Let the ordinary monthly meetings take the form of general discussions of pre-arranged topics of wide scientific interest. It might well be that the authors of papers set down for presentation should give a lecture on some *general* aspect of their subject, and *not* upon the details of the contribution itself. In this particular, I think we too often give the members of our audience credit for a far wider knowledge of general scientific principles than they possess, and far too little credit for a desire to know more. I remember a scientific lecture on colour photography before a general scientific society, in which the lecturer assumed a thorough knowledge of spectrography. The result was that he was hopelessly above the heads of his audience from start to finish, and a carefully prepared and eagerly anticipated lecture became a fiasco.

Can we not remember that, in the midst of the intense specialisation imposed by present-day scientific work, it is impossible for any of us to possess even a nodding acquaintance with the great advances in other branches of science? Cannot our biological friends tell us something, in language fitted for little children, of, say, the status of evolution. Cannot the physicists temper the wind to the shorn lamb and let us have a glimpse into the universe of the atom? Cannot the organic chemist tell us just what he means by optical rotation, and how he

obtains it? In return, we geologists will try to find some aspect of our subject which may be fit for the loftier intellects of the Olympians to consider during their periodical descents to mere earth.

(3). It may be desirable to select, well in advance, certain questions of wide scientific interest, or of universal cultural significance, and to invite certain people to introduce the subjects for general discussion. Even formal debates on such subjects would relieve the tedium which sometimes falls upon our meetings.

The somewhat unsatisfactory state of affairs is reflected in the fact that our membership has declined during the past twelve months. We began the year with 371 ordinary members. During its course 12 have resigned, and 9 have died. Death has been particularly busy in our ranks, and seems to have singled out some of our most prominent scientific workers. Some of them were at an age when it seemed reasonable to expect many years of activity in the researches to which they were devoting their lives. Others had approached closer to the allotted span before they left us.

JOSEPH JAMES FLETCHER, M.A., B.Sc., was born in Auckland in 1850. He was the son of Rev. Joseph Horner Fletcher, who for many years was Principal of Newington College. He received his education at the Ipswich Grammar School, and at Newington College, and proceeded to the University of Sydney, where he gained the M.A. degree in 1876. He went to Melbourne to teach at Wesley College. After six years there he proceeded to England for scientific study, and obtained the B.Sc. degree of the University of London.

On his return to Australia he became senior house master at Newington College, and many of his old students speak of him with great affection and appreciation.

In 1881 he became closely associated with the Linnean Society and with Sir William Macleay, its founder and patron. His life was chiefly devoted to the interests of that Society, of which he was Secretary for no less than 33 years. In addition to secretarial work he edited the Society's Proceedings, and a most exact and painstaking editor he was. Many of us gained our first experience in publishing the results of scientific investigations under his guidance; and if we, as beginners, sometimes resented his insistence upon what at that time appeared to us to be trivial details, we have lived to be grateful for the lessons so given us. He was far from being content with purely routine duties, exacting as they were; but found time to make numerous valuable original contributions to science. In the earlier part of his career his papers dealt chiefly with zoological subjects, and, in later years, he also contributed very valuable botanical papers.

In addition to being President of the Linnean Society in 1919 and 1920, he was President of the Biological Section of the Australasian Association for the Advancement of Science in 1900, and received the Clarke Memorial Medal of this Society in 1921. He was also a Trustee of the Australian Museum. His membership of this Society extended from 1921 to the time of his death on 15th May, 1926.

Hector Kidd, who was elected a member of this Society in 1901, was born in Scotland in 1847, and died in Sydney on 31st May, 1926. He came to Australia as a lad and went through his apprenticeship as an engineer. He served at sea for some time, and was chief engineer in various mills of the Colonial Sugar Refining Company in New South Wales, Queensland and Fiji. Later he became inspecting engineer for the same company. After his retirement from this position he became consulting engineer

for several important Sydney interests. In 1893 he attended the Sugar Convention in Chicago, as the Australian representative. He was a Member of the Institute of Civil Engineers, and a Member of the Institution of Mechanical Engineers.

William Freeman, elected a member in 1907, died on 18th July, 1926, at the ripe old age of 80 years. For over 45 years he was connected with the Lands Department. He was secretary of the National Park Trust for many years, and was largely responsible for laying out the park and the surveying of the Lady Carrington Drive. He was keenly interested in horticulture and forestry, and served as a Royal Commissioner in an enquiry into forestry matters. His public services also included chairmanship of various land boards, chiefly in the northern districts of New South Wales.

Charles Hedley, F.L.S., who died suddenly in Sydney on 14th September, 1926, came to Australia in 1882 for health reasons. He made several attempts to settle on the land, with rather indifferent success, and went to Brisbane in 1888. There he became connected with the Brisbane Museum, at first in an honorary capacity, and afterwards in charge of Shells, Radiates, Tunicates and Polyzoa. He was chosen by Sir William MacGregor as naturalist on his staff when he was Administrator of Papua, and always retained a love for scientific work in the tropics. He came to Sydney in 1890 and entered the service of the Australian Museum in 1891 as Assistant in charge of Land Shells. His connection with the Museum continued for over 30 years, and he occupied the positions of Conchologist, Assistant Curator and Acting Director. While he is chiefly known as a conchologist, he was a man of extraordinary breadth of outlook and wrote important papers on many other branches of science, amongst which ethnology,

physiography zoögeography may be specially mentioned. An indefatigable worker, he was so methodical in all he did that he was able to publish a bulk of material seldom surpassed by a single individual.

He was also a tireless traveller. Although always more or less delicate, he possessed extraordinary powers of physical endurance, and, even in the later years of his life, set a pace which even much younger companions found very exacting. His passion for travelling led him into many out-of-the-way places.

In 1896 he was biologist to the expedition led by Professor Sollas to bore on the atoll of Funafuti. He contributed extensive and valuable accounts of the zoology and ethnology of that island.

In 1904 he visited the Great Barrier Reef, in continuation of his studies on coral reefs begun at Funafuti. From that date onwards, the Barrier Reef became his favourite hunting ground; and, even up to the time of his death he actively pursued his researches in connection therewith.

He was largely instrumental in the appointment of the Barrier Reef Committee by the Royal Geographical Society of Australia*; and, having retired from active work at the Museum, spent most of the rest of his life in close association with the various expeditions which have been exploring the reef, nearly continuously, since that date. For some time before his death he was superintending the sinking of a bore on Michaelmas Cay near Cairns, to test the theories he had been led to propound in connection with the structures of coral reefs. This work he relinquished in order to make preparations for his intended visit to Japan on the occasion of the Third Pan-Pacific Science Congress in October last. His passage was actually booked, when illness seized him and he was compelled to

* Queensland Branch.

cancel his engagements. No untoward results were anticipated, and his friends were inexpressibly shocked to hear of his sudden death on 14th September, 1926. In accordance with his own request his remains were cremated, and his ashes strewn on the waters of the Great Barrier Reef by the members of the Australian contingent of scientists on their way to Japan.

Hedley was an invaluable member of many scientific societies. In addition to his personal scientific investigations, he served on their councils and his contributions to debates were always marked by shrewd common sense and by a breadth of outlook not always shown by men of science. He was a member of this Society for 35 years, and of its Council for 16 years, and was its President in 1914. He was President of the Linnean Society of New South Wales in 1909 and 1910, and of the Zoological Society for some years. He was awarded the Clarke Memorial Medal in 1925.

SYDNEY DODD, D.V.Sc., elected a member in 1913, died on 22nd October, 1926. He was lecturer in pathology and bacteriology at the Veterinary School in the University of Sydney.

He was trained at the London Veterinary College, and was a Fellow of the Royal College of Veterinary Surgeons. After a considerable amount of experience in London he went to South Africa to take up a Government post. Next he became Veterinary Pathologist to the Queensland Government, and in 1911 accepted the position which he held till the time of his death.

FREDERICK BICKELL GUTHRIE, born in 1861, became a member of this Society in 1891, and died on 2nd February, 1927. His father was Professor Frederick Guthrie, F.R.S., Professor of Physics at the Royal School of Mines. He was educated at University College, London, and at the

University of Marburg. After holding several teaching positions in institutions of University status in Great Britain and Ireland, he came to Sydney as Demonstrator in Chemistry at the University in 1890. In 1892 he became chemist in the Department of Agriculture, which position he retained until his retirement a few years ago. On several occasions he held the position of Acting Professor in Chemistry at the University, and in 1907 was appointed Lecturer in Technology.

His chief interests were in chemistry as applied to agriculture. He devoted much of his energy to soil analysis, and to investigation of wheats from the point of view of their milling qualities. He contributed many valuable papers on these subjects.

He was President of the Association of Official Agricultural Chemists of Australasia, and was an original member of the Commonwealth Advisory Council of Science and Industry, and of the Australian Chemical Institute. He was also a very old member of the Australasian Association for the Advancement of Science, and was President of the Chemistry Section in 1901, and of the Agricultural Section in 1913.

He was President of our own Society in 1903, and acted as one of its joint Honorary Secretaries from 1906 to 1910.

Francis John Thomas, who died on 12th October, 1926, at the advanced age of 88 years, was elected a member of this Society in 1878, and was therefore a member of it for more than the lifetime of many of us here to-night. Active to the very end, he met his death as the result of a street accident in the city. He came to Australia at an early age, and saw a good deal of the early gold rushes in Victoria. In 1859 he became a clerk in the Hunter River New Steam Navigation Company, and remained connected with the Hunter River transport ser-

vices up to the time of his death. In fact, he was on his way to a board meeting, of which he was acting chairman of directors, at the time when he was run over. While not an original contributor to scientific investigation, he took a great deal of interest in the affairs of our Society.

THOMAS HENRY FIASCHI, D.S.O., M.D., Ch.M., was born in Florence in 1853, and was the son of a University Professor. He received his education at the Universities of Pisa and Florence. After taking the degrees of M.D. and Ch.M., he came to Australia at the age of 22 and built up a magnificent reputation as a surgeon. He held many important positions in connection with his profession, including those of consulting honorary surgeon to the Sydney Hospital, and examiner in Clinical Surgery to the University.

Always keenly interested in military matters, he joined the New South Wales Army Medical Corps in 1891. In 1896 he went to Abyssinia with the Italian Army as a medical officer, and from 1898 to 1900 was in charge of the New South Wales No. 1 Field Hospital in South Africa. He was mentioned in despatches by General Hutton and received the D.S.O.

Dr. Fiaschi served with distinction in the Great War, first with the Australian Imperial Forces, and later with the Italian Army on the Austrian Front.

He was extremely active in all the associations connected with his profession, and was one of the foundation members of the New South Wales Branch of the B.M.A. He was for many years President of the Australian Trained Nurses' Association.

In addition to the vast amount of surgical work which he was able to get through, he was a leading authority on viticulture, and planted vineyards on the Hawkesbury and elsewhere. He was President of the New South Wales

Wine Association, and a member of the Council of the Royal Agricultural Society.

A fluent speaker in English, Italian and French, he had a wide knowledge of literature, and was President of the Dante Aligheri Society at the time of his death.

Joining our own Society in 1881, he took a keen interest in its activities. He frequently attended our ordinary meetings, and was rarely absent from the Popular Lectures.

WILLIAM JOHNSTONE NEWBIGIN died with tragic suddenness on 20th April, 1927. Though he had been a member of our Society for less than a year, his appointment as a member of the Executive of the Commonwealth Council for Scientific and Industrial Research placed him in a position of great importance in connection with scientific development in Australia. He had taken his duties in this connection very seriously, and was about to assume the position of Acting Chairman of the Council during the absence of Mr. Julius. One short week before his death he formed one of a party to inspect possible sites for the proposed Scientific Societies' House.

I feel that I must refer also to two other distinguished men of science, who died within a week of one another, although they were not, at the time of their deaths, members of this Society. Australian science is poorer for the loss of Professor Abercrombie Anstruther Lawson, D.Sc., F.R.S., F.L.S., and James Matthew Petrie, D.Sc., F.I.C. Professor Lawson, the first occupant of the Chair of Botany at the University of Sydney, had a most distinguished career as a botanist. This was fully recognised by his contemporaries, and news of his election as a Fellow of the Royal Society of London reached Sydney less than a week before his sudden death.

Dr. Petrie was well known in Sydney for many years as a chemist. A native of Scotland, he came to Sydney

as a young man, and taught in the Technical College and the University of Sydney for some time. Later he took his degree in Science, and was one of the earliest Doctors of Science in our University. For many years he was a Macleay Research Fellow of the Linnean Society of New South Wales, and did admirable work in Biological Chemistry. At the time of his death he was attached to the research staff of the Cancer Research Laboratory at the University of Sydney.

I have to acknowledge with thanks the assistance of Dr. Waterhouse and Mr. Cambage in the preparation of this portion of my address.

Walter Burfitt Prize.

It is very pleasant to be able to turn from the sadness inseparable from this long list of obituaries to a theme of quite another character.

In the United States, and to a less degree in Europe, it is customary for well-to-do citizens to recognise the work which is being done for humanity by science in all its forms. Gifts and bequests to Universities and learned societies are by no means rare, and are sometimes on a very lavish scale.

It is an excellent habit for any community when its wealthy men thus encourage learning—a habit which we like to encourage in every way possible. It is a habit not unknown even in Australia, as the endowments of our Universities prove; but it is a habit by no means so common as we should like to see it.

Our own Society, the senior scientific society in the Commonwealth, is sadly deficient in endowment. It is with special pleasure then, that I am able to announce to you that one of our life members, Dr. Walter Burfitt, has come forward to blaze the trail for others to follow, we

hope. He has very generously offered to present to the Society a sum of £500, to found an annual prize, called the Walter Burfitt Prize, to be awarded at the discretion of the Council to a person, resident in Australia or New Zealand, for meritorious service in the cause of science during the year.

Long may Dr. Burfitt be spared to become personally known to the succession of distinguished workers who shall receive the Prize bearing his name!

PART I.

The Chemical Criteria of Peneplanation.

One of the most fertile conceptions introduced into geology within the last fifty years or so is that of the peneplain, suggested by W. M. Davis. The clue thus provided enables us to decipher the details of the latest phases in geological history, phases for the elucidation of which ordinary geological criteria are largely lacking. The latest marine sediments are only in very few cases uplifted above the waters in which they were deposited: and, even then, are not dissected by erosion to a sufficient extent to permit of their full history being unravelled.

The conception of the base-level of erosion has enabled geologists and physiographers to determine with certainty the records of changes in sea level during the Cainozoic time.

The physiographic criteria of peneplanation are too well known to need repetition here; but there are some implications to which I have not seen attention directed so explicitly. For instance, there appear to me to be certain chemical criteria of peneplanation quite as conspicuous and important as are the physical evidences.

Davis and his disciples have all insisted upon the fact that a peneplain *is necessarily carved out, by sub-aerial*

erosion, to form a gently curved and gently inclined surface lying very close to sea level in the general case. The early stages in the production of such a surface from an uplifted land area are geologically extremely rapid. Mechanical abrasion and transportation are the dominant activities of the agents of denudation; chemical effects are very subordinate. The mechanical forces remove the rock materials almost as soon as they have been loosened by chemical action, and thoroughly decomposed rock is almost a rarity. In this mechanical work, running water is much the most active agent. As the gradient of the streams is reduced as a result of vertical corrasion, the rapidity of the work falls off. The *final* stages of base-levelling are almost inconceivably slow. This is the reason why we so seldom, if ever, recognise an *ideally* perfect peneplain.

After a prolonged period of crustal stability, the accumulation of earth stresses usually causes earth movement, and uplift or subsidence supervenes. This being so, even during the penultimate phases of the process as ordinarily carried out, there is still an effective run-off of the stream drainage, sluggish though such drainage may be. If, however, vertical movements of the crust are so long delayed that the entire surface is reduced to the ideal base-level of erosion, and is left devoid of any appreciable remnants of the older high lands from which it was evolved, the lateral drainage of surface waters must be inhibited almost completely. What flow there is must be so leisurely as to be incapable of transporting, in suspension, solid mineral matter other than that in the finest state of subdivision. Colloidal suspensions may still exist, and it is such emulsions, together with true solutions, which must be responsible for any further degradation of the land surface.

Hence, when peneplanation is forced to its extreme limit, *chemical action completely dominates over mechanical processes of corrasion.*

Such sluggishness in the lateral circulation of surface waters favours deep saturation of the subsoil, and long continued contact between rock minerals and meteoric waters. These conditions result in a high degree of perfection of rock weathering. In all but the most extreme cases of base-levelling, the disintegrated solid products of weathering are removed almost as fast as they are formed by means of mechanical transportation in the waters of the run-off. The efficiency of weathering is somewhat obscured thereby. On the other hand, retention *in situ* of the insoluble residue becomes the outstanding feature when peneplanation is carried to its logical limit.

This deep and perfect weathering is frequently referred to, implicitly, in descriptions of peneplains in an advanced stage of development; but I have not noticed a definite statement of the fact as an *explicit criterion* for perfection of the process.

The actual details of resulting structure vary according to the climatic conditions of the region. In pluvial climates saturation of the weathered material is complete and permanent. The rainfall soaks downwards and laterally, and little or no ascent of sub-surface waters can take place. Consequently, the downward extension of oxidation, carbonation and hydration, that trinity of reactions mainly responsible for rock weathering, is hindered. In such circumstances, the effective depth of complete weathering may be somewhat restricted. The mantle of swampy vegetation, favoured by the conditions outlined, acts mainly as a protection for the surface; even the small amount of run-off possible on a bare horizontal surface being materially lessened by the vegetable mat. The latter holds the water tenaciously, and filters out of it the small modicum of solid matter it has been able to pick up. Waters draining through swamps are notoriously free

from mechanical sediment. On the other hand, they are charged with organic acids which, no doubt, contribute their quota to the process of deep weathering.

Excessively slow though it may be, there must always be a seepage of ground water towards the drainage sump. This is effective in removing the *soluble* products of rock decomposition, and also some of the suspensoid systems. Given sufficient time, the soil and subsoil must be leached completely of all soluble materials. All the alkalies, alkaline earths, and magnesia are removed. Most of the iron and some of the alumina are got rid of in the form of soluble salts, and still more in colloidal form. Some of the silica, also, is dissolved by the alkaline solutions, and some goes in colloidal suspension. All that can be left in the residue are absolutely insoluble minerals which are stable under subaerial conditions. Silica, chiefly as quartz, gibbsite, diaspore, kaolin, and such minor constituents as zircon, rutile, xenotime, cyanite and so on, build up the bulk of the residue *in situ*.

It must be remembered that the results described above are those which are to be expected when peneplanation has reached *absolute perfection*. For the reasons already stated, such perfection is very rarely attained, and the results halt at some point short of ideal completeness. In particular, the removal of the iron and alumina is apt to be imperfect.

The direct antithesis to pluvial conditions of climate is supplied by those of extreme aridity. Such conditions, however, do not seem capable of leading to the development of a peneplain. Arid basins become filled up with detritus, to form vast extents of plain, chiefly as the result of such processes as insolation, ablation and salt weathering. Such ultimate structures belong to a category entirely different from those described here, and need not be considered further.

In contrast with the pluvial conditions outlined above, we may consider the case of perfection of peneplanation in a region with a climate marked by strongly contrasted periods of saturation and desiccation. Such alternations may be annual, as they are at the present time over a great part of the coastal portions of Australia; or they may be of longer duration, as in the interior sub-arid regions of most continents. In either case the general effect is the same, though there are doubtless differences in matters of detail.

In such a case the mat of vegetation is less permanent and continuous than is the case in a pluvial climate, a condition slightly more favourable to surface run-off. Nevertheless, the removal of solid matter in suspension in running water is very insignificant, since the gradient of the streams is, by hypothesis, negligible. During wet seasons meteoric water is greedily absorbed by the parched soil and subsoil. So rapid is the sinking in of the water, assisted as it is by a network of cracks, large and small, that the gases dissolved from the atmosphere are carried immediately to considerable depths. There is not, as in pluvial climates, so gradual an abstraction of oxygen and carbon dioxide from the surface downwards. On the other hand, these active constituents are fairly uniformly distributed throughout a considerable vertical zone. During their contact, long or short, with the rock minerals, the waters carry on their processes of decomposition. These effects are cumulative, and the final result is decomposition, at least as profound as that which is effected in a pluvial region. It is in the subsequent destinies of the solutions that there is a marked difference.

In a region with seasonal rainfall, the period of saturation is succeeded by one of desiccation. As the surface soil becomes dried, capillarity supplies moisture from the

deeper levels of the soil and subsoil. Thus, upon the slow *lateral* seepage of solutions characteristic of the other type of climate, there is superimposed a movement *vertically upwards,* of a relatively extremely pronounced and active type. Large amounts of dissolved material are drawn towards the surface. The more soluble constituents may reach the daylight, there to be deposited as an efflorescence if the desiccation is sufficiently complete. During each successive wet season these soluble salts are moved laterally in the direction of the drainage, the sluggishness of the current being immaterial when *dissolved* load, only, is considered. In most regions of this type, specialised types of vegetation have been evolved which are capable of dealing effectively with the salt solutions; and any noteworthy accumulation of salt is prevented, unless quite extensive "sumps" occur along the line of drainage. If, however, the mantle of native vegetation is removed, this natural safeguard is interfered with, the rate of run-off is accelerated, and very serious "salting" of the lower levels may occur. Such a process may be seen at work in parts of the Wheat Belt of Western Australia.

Under normal conditions, however, the most soluble, saline fraction of the products of weathering (chiefly salts of alkalies and alkaline earths) is removed and carried seawards in much the same way as it is in a pluvial climate. It is the less soluble constituents, and particularly those of a colloidal character, which behave in markedly different fashions under the two sets of conditions. Produced in the subsoil under conditions of complete saturation, and of definite hydrogen-ion concentration, they encounter conditions rapidly altering in every respect as they migrate towards the surface during the dry season. Usually, long before they reach the open air, the character of the solvent has changed to such an extent that precipi-

tation of the colloids supervenes. This generally takes place around a number of isolated nuclei in the subsoil. Hydroxides of aluminium and iron are most colloidal when precipitated in the cold and from dilute solutions.

During the next ensuing period of saturation the descending solutions which wash over the precipitated colloids approximate much more closely, in hydrogen-ion concentration, to those which produced precipitation than they do to those favouring solution. The latter conditions exist just before the groundwater starts on its *upward* journey at the beginning of the dry season. While, undoubtedly, there is some re-solution of the precipitate, it is likely to be very subordinate in amount. A large proportion of the colloidal matter is left in the subsoil, and accumulates there progressively. In this way there originates a subsoil deposit of mineral matter, *amorphous* because derived from colloidal suspensions, and predominantly nodular or concretionary in habit because of its progressive accretion. Such substances as hydrated silica and hydrated oxides of aluminium and iron are most abundant and conspicuous in such deposits.

Intermediate between the soluble salts completely removed in solution and the colloidal precipitates largely retained in the subsoil are the carbonates of calcium, magnesium and iron, which may accompany either the salts or the colloids, or may be divided between them according to circumstances. On the whole, they belong rather to the former than to the latter category.

I wish, then, to advance as my first thesis that *one essential* criterion of a high degree of perfection of peneplanation is that *the rocks of the area show evidence of very deep and very complete chemical alteration by meteoric waters.*

If the residual material consists entirely of the most insoluble products of rock weathering, a uniformly moist climate may be postulated during the last stages of peneplanation.

If, on the other hand, there is a crust of concretionary, amorphous material, chiefly alumina, iron oxide or amorphous silica, resting upon a substratum of insoluble residual constituents, the final stages of peneplanation took place under climatic conditions marked by sharply defined alternations of saturation and desiccation.

At the risk of wearisome repetition I wish to emphasise the fact that *absolutely ideal* conditions of perfection in peneplanation must be extremely rare. When the conditions are nearly, but not quite perfect, we get a close approximation to the results outlined above. There still remain, however, slight residual differences of elevation of the mature land surface, which, on the one hand, provide positive features whence a certain amount of mechanically transported sediment is removed, and, on the other, negative features in which such detritus accumulates in the form of beds of freshwater sediment. If, then, we encounter patches of such sediments genetically associated with the characteristic chemically formed coatings, the phenomenon need cause no surprise, nor need it be taken as disproof of the thesis advanced above.

In the second part of this address I hope to indicate how perfectly these general considerations are exemplified in the case of formations extremely widespread in Australia.

PART II.

THE DURICRUST OF AUSTRALIA.

THE "LATERITE" OF WESTERN AUSTRALIA.

An almost ideally perfect example of the type of structure produced by peneplanation in an area of seasonally

wet and dry climate is afforded by the Darling Peneplain of Western Australia, with its highly characteristic "laterite" deposits. It is not necessary, in this place, to describe its features in detail, as they have been referred to by numerous investigators.[13, 16] It may be pointed out that the name "laterite", used for the characteristic concretionary formation, has given rise to some confusion, as the rock called by that name in India and elsewhere is of quite a different character and mode of origin.

Suffice it to repeat, here, that the "laterite" of the Darling Ranges of Western Australia is characterised by fairly abundant "soluble" silica, and is dominantly bauxitic or götitic according as the underlying (Pre-Cambrian) crystalline rocks are acid (granite) or basic (greenstone) respectively. The concretionary "laterite" rests *directly* upon very thick "fireclays", composed of minerals perfectly in equilibrium with atmospheric conditions. That the formations in question have been produced absolutely *in situ*, and have not suffered the slightest degree of transportation, is proved conclusively by the occurrence of thin bands of quartz and muscovite in the "fireclays" and "laterites", which can be traced continuously downwards into thin pegmatite veins in the underlying crystalline rocks. One very conspicuous example of this kind is met with in the railway cuttings at Hoddy's Well, between Clackline and Toodyay.

Extensive and almost unique opportunities for travelling widely through the more remote parts of the interior of Australia during the last sixteen years, have suggested to me that there is a considerable variety of formations showing analogies with the "laterites" of Western Australia.

I venture to suggest as my second thesis that, not only have these rocks been developed under similar conditions,

but that they have been produced homotaxially over a very large part of Australia, during an era of highly perfect peneplanation, combined with a climate in which alternation of intensely dry seasons with very wet ones was the characteristic feature. These rocks constitute, therefore, a definite geological formation, recognition of which, as such, clears up a number of points in the geology of the continent, which were previously very obscure.

EQUIVALENTS OF "LATERITE."

The dependence of the "laterite", as regards chemical composition, upon the nature of the underlying crystalline rock, has long been insisted upon: the wide extent of the generalisation is not so well recognised. The key to the problem is best found in the superficial rocks of the Irwin River Valley of Western Australia.[18] Without going into details, the formation, called by Somerville and myself "The Plateau Beds", shows a variation in composition most markedly sympathetic with the nature of the underlying rock formations. Where, as on the eastern side of the valley, the basement consists of granite and greenstones, the hard capping of concretionary rock at the surface is represented by the normal "laterite" of Western Australia. On the summits of isolated mesas and buttes within the valley, where the bed-rocks are Permo-Carboniferous clays, marls and tillites, the "Plateau Beds" are indurated claystones, passing into porcellanites with veins of common opal. On the western side of the valley, where porous siliceous sandstones of Jurassic age are extensively developed, the capping consists of hard, somewhat ferruginous siliceous sandstones, passing in places into quartzite. In every instance, and in spite of individual differences, the hard crust rests upon a considerable thickness of decomposed material. The latter is of economic importance, as it holds fair quantities of water. This seeps into the

sides of the valleys, producing "soaks" which constitute the most reliable natural water supplies of the region.

All these various hard cappings are so related as to be obviously portions of a once-continuous "armour-plate" of rock material, produced by chemical processes in the manner detailed in Part I. above. From the fact that, no matter what may be the nature of the underlying rock or of the chemically formed covering, the latter always appears as a relatively hard "armour plate", protecting softer, decomposed rock residue beneath it, I propose to group together all the representatives of the hard crust, in every part of Australia where they can be shown to have formed in the same manner, during the same geological period, under the name of THE DURICRUST.*

With this significance, the Duricrust is almost ubiquitous in Western Australia. While "laterite" is its most widespread and conspicuous representative, it can be traced in a great variety of rock types throughout the South Western Division of the State, and through the Eastern Goldfields. Everywhere it is obviously connected genetically with the great peneplain level of Western Australia. Even should the evidence, to be submitted below in favour of its wider extension throughout Australia, prove unacceptable, its enormous extension in Western Australia should, I think, be sufficient to entitle it to formational rank.

* This name was suggested to me by Professor Todd, Professor of Latin in the University of Sydney. He also suggested the names "petroderm" and "lorica"; but I have preferred the name used above, since "petroderm" has been employed by Walther in a somewhat different sense, and "lorica" is preempted by biological usage. Though the "crust" part of the new word is derived originally from the Greek, I understand that it is quite good Latin, so that duricrust cannot be looked upon as an undesirable hybrid.

Where the Duricrust has suffered from subaerial erosion, the land forms which result are in the highest degree characteristic. The hard capping, resting upon a considerable thickness of thoroughly decomposed rock material, produces an extremely weak structure. As soon as the agents of denudation pierce the crust, erosion proceeds rapidly. Steep-sided gorges result. By rapid widening of these, extensive valleys are carved out, and, as adjacent valleys become united, residuals of characteristic shapes are developed. At first they appear as mesas of considerable extent. As development progresses, their flat tops decrease in area until, finally, typical buttes remain. The extremely wide distribution of such land forms, associated with the crust and substratum characteristic of the Duricrust, throughout a very large part of Australia suggests that the Duricrust may be very widely distributed.

I have previously suggested[16,17] that the "laterite" of Western Australia is thicker on the western part of the surface of the Darling Range, and over the Eastern Goldfields, than it is in the intervening Wheat Belt. This fact I believe to be due to the sea having extended over much of what is now the Nullarbor Plain, so that the Eastern Goldfields were actually coastal areas at the date of formation of the peneplain. Duricrust formation was much more pronounced in such coastal regions, with their high annual precipitation, than in the inland areas, now constituting the Wheat Belt. Consequently, the land forms most characteristic of the Duricrust, both in the Darling Ranges and in the Goldfields, are not developed clearly in the Wheat Belt. Though this is the case, there are not wanting traces of the formation. Apparently in these areas during the great era of peneplanation the rainfall was too light to effect the complete decomposition of the rocks which took place nearer the coasts. Instead,

we find that the granites, in particular, are weakened by weathering to a considerable depth, and superficially "case-hardened", without that complete redistribution of elements which is characteristic in somewhat more humid regions.

This "case-hardening" of the granites has been, I think, the most important factor in the production of "gnamma-holes", those invaluable sources of water supply throughout the arid regions of Western Australia. No doubt small breaks in the "case-hardened" surface containing small supplies of water, have been enlarged and improved by marsupials and man. The incoherence of the sub-surface layers of the rock has assisted very materially in enabling animals, very indifferently equipped with digging tools, to excavate not inconsiderable reservoirs.

DURICRUST IN THE NORTH WEST.

Personal observations by me have not extended into the North Western Division of Western Australia; but descriptions and photographs indicate that the Duricrust retains its dominating influence in this part of the continent. In particular, I may mention that, having discussed my theory with Mr. F. Clapp before he visited this area in connection with his search for indications of petroleum, he paid special attention to evidences of the formation. On his return he expressed himself as being convinced of its applicability to the district in question.

"DESERT SANDSTONE."

The wide extent of typical mesas and buttes, with "case-hardened" cappings, throughout Central Australia is well known. For a long time the opaline quartzite or sandstone, found almost ubiquitously over northern South Australia, north-western New South Wales and the whole of the western part of Queensland, was referred to Upper Cretaceous, and called "Desert Sandstone".

It was Daintree[4] who in 1872 first used the term Desert Sandstone. A few of his statements may be quoted.

"On the eastern branches of the Upper Flinders River and elsewhere, fine sections are exposed of lava resting on horizontal beds of coarse grit and conglomerate, which lie in turn unconformably on olive-coloured and grey shales with interstratified bands and nodules of argillaceous limestone containing fossils of Cretaceous affinities. I have called this upper conglomerate series Desert Sandstone. . . . All that can be asserted [as to its age] is that its horizon is above and unconformable to the Cretaceous series of the Flinders."

"Without doubt it is the most recent, widely-spread stratified deposit developed in Queensland. . . ."

"A view of the cliff section of Desert Sandstone, with outlier, is represented in the accompanying woodcut." The picture in question reveals the standard topographic types produced by denudation of the Duricrust in any of its manifestations.

"All available evidence tends to show that this 'Desert Sandstone' did at one time cover nearly, if not quite, the whole of Australia, with the probable exception of the south-eastern corner of the continent from the Cordillera to the ocean."

Palaeontological difficulties began to accumulate as time went on. One well-known case of this kind was the reported discovery in 1891, by Rands,[11] of *Glossopteris* in Upper Cretaceous rocks at Bett's Creek, North Queensland. The discovery was confirmed by no less a geologist than Dr. Jack, and the true explanation was not forthcoming until 1916, when Reid[12] showed that the *Glossopteris* occurred in Permo-Carboniferous beds, superficially altered and "case-hardened" in exactly the same manner as are beds of similar age in the Irwin River area of W.A.

DURICRUST IN CENTRAL AUSTRALIA.

Personal observations of the hard cappings in the extreme south-west of Queensland and the north-eastern corner of South Australia have convinced me that they are chemically formed rocks identical in mode of origin with the "laterites" and associated rocks of Western Australia.

Close to the border line between the two States, in the neighbourhood of Innamincka, there are inliers of gneissic granite surrounded by the Cretaceous sediments of the Great Artesian Basin. In both granitic and sedimentary areas there are thoroughly typical residuals of Duricrust, of varying composition, but identical as regards the land forms to which they give rise. Further to the north, in the extreme north-eastern corner of South Australia, the dominating positive land forms are "table hills", "tent hills" and "sugarloaves". These have their surfaces composed of "case-hardened" siliceous rock, resting upon a thick bed of completely weathered rock material. The latter consists of "white pipeclay" and "red ochre" which have been mined, as pigments, by the aborigines from time immemorial. The undercutting of the hard cappings, largely through ablation, has developed great overhanging cornices, under which are quite extensive shelter caves, long tenanted by man and beast. As in Western Australia, much of the limited surface water supply of the region is met with, in the form of "soaks", seeping from the decomposed material below the Duricrust.

To the west of the Great Salt Lakes of South Australia, between them and the Flinders Ranges, there are great extents of Duricrust. They form a capping over clays and marls of Winton Age, overlying the Lower Cretaceous beds of the Artesian Basin.[18,19] The Duricrust is in the form of dense, intensely hard, opaline sandstone, the desir-

able qualities of which have been abundantly recognised by the aborigines. Near the permanent spring at the foot of Mt. Parabana, near Moolawatana Station at the northern end of the Flinders Ranges, there are aboriginal quarries on a colossal scale. Literally thousands of tons of rock have been chipped and flaked to obtain material for spear-heads and other weapons and implements. The discarded debris covers the surface of the foothills over many acres in proximity to the spring.

All the Duricrust in this locality possesses a more or less well marked concretionary structure. Sometimes this results in spheroidal nodules; but, in some instances, the concretions are much elongated in a direction perpendicular to the original surface. Each nodule is circular in cross section, but its length may be many times its thickness. The effect is to produce individuals, "stalactitic" in shape, but inverted in attitude.

In one place, near Moolawatana, the average diameter of the nodules is over three feet, and they reach a length of at least fifteen feet. Where, as is more usually the case, the inverted stalactites are more slender, they produce ready-made "phallic stones" some of which are extraordinarily realistic. Those about a foot long by two inches in diameter were much prized by the aborigines, and have apparently been traded to other tribes at considerable distances.

One feature of extraordinary interest is encountered in this locality. Whereas, over almost the whole of Australia, the remnants of the Duricrust are horizontally disposed, along the eastern margin of the Flinders Range there has been considerable movement subsequent to the date of its formation. Just south of Moolawatana Station, the Duricrust, together with its decomposed sub-stratum, is sharply folded, and, in some cases, actually over-folded

monoclinally. The depression is in the direction of the lake basins, and the overturning is from the Flinders Range towards the east. In addition to this folding along the strike, there has been subordinate dip-faulting, so that the Duricrust remnants are disposed *en echelon*.

To judge by a very recent publication of the Geological Survey of South Australia,[6] the usage in that State is still to consider the "Desert Sandstone" as Upper Cretaceous, and the beds above the Lower Cretaceous marine beds of the Great Artesian Basin, that is, the equivalents of the Winton Beds of Queensland, as Middle Cretaceous. In the paper mentioned Jack does not bring forward any evidence opposed to the suggestion that the "Desert Sandstone" may be considerably younger than Upper Cretaceous. The evidence of the folded Duricrust at Moolawatana (described above) is not inimical to the younger age I have suggested.

Jack refers to the occurrence of water supplies immediately below the crust (Duricrust).

The remnants of "Desert Sandstone" in Central Australia, including the very numerous "tent-hills", and buttes like Chamber's Pillar, appear to be identical in every respect with the structures I have personally examined further to the south. The Duricrust here covers bed rocks of widely different ages and characters.

To the west of Lake Torrens, there is an extensive development of rocks of the Adelaide Series. In spite of their great age they are horizontally disposed, a fact which obscures, to some extent, the development of Duricrust. Even here, however, the case-hardening of the upper layers is ubiquitous.

Very typical Duricrust is developed between Lake Torrens and Lake Eyre, and Coward's Bluff is an ideally perfect example of the structure.

DURICRUST IN NORTHERN TERRITORY.

In the Northern Territory, so far as my personal observation goes, the development of the Duricrust is quite normal, though, perhaps, somewhat less conspicuous than is the case in Western Australia and South Australia. The escarpements which everywhere hem in the valleys of rivers like the Roper and Macarthur, and mark off the edges of the plateaux, indicate that the topmost beds of the cliffs have undergone a process of chemical impregnation. The plateau surfaces here, as elsewhere in Australia, are remnants of a very completely developed peneplain. The profiles of individual hills, such as Mt. McMinn on the Roper River, repeat exactly those of the typical "laterite" covered hills of Western Australia. I am inclined to believe that the hard red beds, called by me the Mt. McMinn Beds in 1912, may belong to the Duricrust, at least so far as their upper surfaces are concerned. The main body of the Mt. McMinn Beds must still be referred to the Roper Series.

Even so far north as Darwin there appear to be indications of a continuation of Duricrust conditions. The sandy claystones with *Belemnites* at Stokes' Hill, Darwin, and the chalky cliffs at Fanny Bay, have harder crusts towards their surfaces. About East Point there are heavy masses of ferruginous "laterite". At Point Charles the very abundant cephalopod fossils are met with in the form of casts in "lateritic" iron oxides.

The account given by Dr. Jensen[7] of the superficial rocks of the Northern Territory seems to me to point very clearly to the widespread occurrence of the Duricrust. He says (p. 5):—

"Not only Tenison Woods, but many other geologists have referred to the sandstone formations of the Northern Territory as Desert Sandstone. While this name is very

accurately descriptive as a lithological term for the various sandstone formations of the Northern Territory, it would be very wrong to think that the enormous sandstone areas of this country consist of a formation of one geological age and are contemporaneous with the Cretaceous Desert Sandstone of Queensland. It is true, as Tenison Woods remarks, that in the Pine Creek, Darwin and Victoria River Districts, the sandstones do not form a continuous tableland, but broken patches of tableland overlying the older formations. . . . .

"The term Desert Sandstone has been misapplied to at least four distinct ages of rock, viz.:—

(1) To Cambrian sandstones and quartzites and Red Beds (McMinn Beds).

(2) To Carboniferous sandstones and quartzites and Red Beds.

(3) To Cretaceo-Tertiary sandstones and Red Beds.

(4) To Recent sandstones and conglomerates formed by the induration of fluviatile and ash deposits by means of capillary waters and hot springs."

As he proceeds to explain (p. 7), there are three distinct kinds of surface crusting—(1) lateritic, (2) magnesian, (3) siliceous. Rejecting, very properly, the suggestion that these are due to extensive volcanic action, for which there is no other evidence, he explains them, in part, by an action somewhat similar to that which I have outlined in Part I above. His statement of the question stresses, as is only natural, the existence of a *pluvial* and *tropical* climate as essential factors. From the very wide extension of similar features in the temperate and semi-arid parts of Australia I think that this is not necessary, and that strongly marked seasonal rainfall in almost any climate can do the work.

If my interpretation is correct, and the various hard cappings are parts of the Duricrust, the red coloration *is of* diagnostic importance, not, as I erroneously supposed in 1912, as an indication of McMinn Beds of Cambrian age, but of the existence of peneplain conditions of a high degree of perfection somewhere in Tertiary time. The conspicuous repetition of "Red Beds" in Jensen's list of formations marks something more than a mere coincidence.

It is to be noted that Jensen's Group 4 (Recent sandstones, etc.) needs to be accounted for otherwise.

DURICRUST IN QUEENSLAND.

So far as Queensland is concerned, detailed personal observations by me are confined to the extreme north-western and south-western portions. The latter have been considered in describing conclusions with regard to South Australia.

In the Cloncurry District, Duricrust conditions are exceptionally well exhibited. The extreme diversity of the bed rocks of the area is well known. Nevertheless, the characteristic hard-capped peneplain residuals are universal. The conspicuous hills to the west of the town are cases in point.

At Mount Elliott, some 80 miles south of Cloncurry, I was able to carry out somewhat detailed observations. At this point the bed-rocks are crystalline schists and amphibolites, presumably of Pre-Cambrian age. Everywhere on the higher land they are covered with a hard siliceous capping, indicated on the older geological maps of Queensland as "Desert Sandstone" of Upper Cretaceous age. This capping is from 3 feet to about 20 feet thick, and rests directly upon a completely decomposed stratum of the bed-rock. To the east and north-east of Mt. Elliott there are great extents of sandstone described by Dunstan[5] as Jurassic. These again are capped by siliceous and

opaline crusts, absolutely continuous with those covering the crystalline rocks, and differing from them only in the proportions of their chemical constituents.

Dunstan, in describing the structures under consideration, speaks of the "laterites" of Soldier's Cap and Selwyn as occurring "in the form of innumerable isolated tablelands which dip away to the east to form an unbroken, gently sloping plain. No doubt the laterites are portions of the Jurassic outcrop and probably were developed as volcanic tuffs".

In this statement he is probably influenced by Tenison Woods.[14] As Jensen[6] has very properly pointed out, there is no necessity to invoke the aid of volcanic processes for the existence of which we have no other evidence. As in the case of similar formations in the Northern Territory, chemical action due to percolating waters is a sufficient explanation for the features observed.

In describing the chalcedonic crusts at Boulia, Dunstan refers them to the silicating action of artesian water. He notes, however, that such an action is *not* going on at the present time. The opaline material forming the cap of the reef at Mt. Elliott he assigns to the same agency. I think that all of these occurrences are quite easily accounted for by the theory of the Duricrust.

The complexity of the problem of the "Desert Sandstone" in Queensland may be indicated by a quotation from an introductory note by Dunstan[12] to a description by Reid of the *Glossopteris* beds at Bett's Creek. He says:

"In the following pages references are frequently made by Mr. Reid to the old term 'Desert Sandstone', and this is hardly avoidable in view of its long usage and the numerous reports printed on the subject. Our recent observations, however, show that the term is applicable

to formations belonging to as many as five different geological horizons, so that it is necessary to fix the exact position of the 'Desert Sandstone' referred to."

Rand's[11] description of the locality in question, quoted *in extenso* by Reid, shows how easily the confusion between Permo-Carboniferous *Glossopteris* beds and "Upper Cretaceous Desert Sandstone" was brought about by reason of the lithological characters of the Duricrust. I am strongly of opinion that the recognition of the latter as a definite geological formation will prevent many such instances of confusion in the future.

The probable extension of the Duricrust into the eastern part of Queensland is strongly suggested by many accounts, of which the following may be selected as typical.

Ball[2] mentions that the report of a former Government Geologist that the capping of Mount Mulligan was Desert Sandstone induced prospectors to search for opal. The discovery of coal was the direct result.

Marks,[9] in describing the superficial formations of the Charters Towers Goldfield, mentions what is obviously typical Duricrust. He writes:—"That part of the goldfield lying to the west of Southern Cross Creek is almost entirely covered by a stratum of sedimentary rock, which in most places is obviously formed from the detritus of the underlying granite, and consists usually of angular and subangular quartz grains embedded in an aluminous matrix. It is often markedly ferruginous, while the proportion of quartz grains varies greatly, up to what is an ordinary slightly aluminous sandstone. Though usually fine and subangular, the quartz is sometimes well rounded and may include fair-sized pebbles.

"At its edge, this formation usually stands out in prominent escarpments over the granite country, and these

escarpments seldom, if ever, show a thickness of more than 100 feet of the sandstone."

Numerous outliers are bounded by "walls". It is remarked that the universal occurrence of "lancewood" is an infallible indication of the formation in question. This is the case, also, in the Cloncurry-Mt. Elliott District, where the capping is none other than Duricrust.

Near Charters Towers, Little Red Bluff (loc. cit. Plate I) is as typical a Duricrust butte as it is possible to imagine. The picture given by Marks is extraordinarily like Red Hill at Coolgardie and several hills near Mt. Elliott.

Marks[9] says also (p. 10): "The mode of occurrence of the aluminous sandstone is a thin sheet, and where ferruginous the character of the rock itself as seen in the neighbourhood of Charters Towers suggests many of the features of the Indian laterites of the more arenaceous type. . . . .

"Like the Indian, the Charters Towers rock is obviously in part, if not altogether, of sedimentary origin, though in some places, such as near Dillon's Creek, where included fragments of auriferous quartz have not travelled far from the site of their parent reef, *the rock must have originated practically in its present position from the decomposition or alteration of the granite*". (The italics are not in the original.)

"Though the Charters Towers rock can . . . scarcely be considered as a laterite, in character and mode of occurrence it presents many features similar to the sheet laterites of India, and in its mode of formation presents many of the difficulties that that rock does to a satisfactory explanation."

It would be possible to go on multiplying indefinitely instances of Duricrust from the geological literature of

Queensland. Enough has been said, however, to show that the extension of the theory to that State is quite reasonable.

OPAL AND DURICRUST.

I have not personally examined the conditions in the various opal fields of Queensland, New South Wales and South Australia; but the descriptions given by different observers tally exactly with my own observations[1,10] in other places. We have bed-rocks of various kinds, not exhibiting any noteworthy degree of uniformity, overlain by a thick bed of "kaolin" representing the leached material, and the hard surface capping of opaline quartzite, designated by such expressive names as "shin-cracker". I think there can be very little doubt as to the identity of these structures with the Duricrust.

STRATIGRAPHICAL SIGNIFICANCE OF DURICRUST.

I do not anticipate that there will be the slightest doubt in the minds of Australian geologists regarding the *similarity of origin* of all the structures mentioned, and of many others widely distributed throughout the continent. I wish, however, to go further, and to claim that there is actual *community of origin,* and that the individual parts of the Duricrust are parts of a continuous stratum of chemically formed material, synchronously developed over an enormous area, at all events in the north and west of Australia. In other words, I claim for the Duricrust the rank of a stratigraphic unit. Most of our well-defined stratigraphic units are groups of mechanically formed or organically formed sediments. I do not think that the fact that the Duricrust is chemically formed should raise any insuperable difficulty, if it can be shown that the formation in question was formed continuously and synchronously. Definite palaeontological evidence on this subject is extremely difficult to obtain; but at least no

facts actually opposed to the supposition have been encountered by me.

In all the localities mentioned above, the Duricrust residuals show every possible sign of being portions of a very extensive peneplain surface. What I claim is that they are all portions of *one and the same peneplain surface.* One of the difficulties encountered in any attempt to substantiate this claim is that, in a chemically formed stratum developed on a land surface of very low relief, and during an era of moderate or deficient rainfall, the conditions for preservation of fossil remains are singularly unfavourable. In the vast majority of instances the age of the formation must be determined indirectly.

Following Jutson,[8] I have suggested[17] that the age of the Darling Peneplain of Western Australia is about Miocene.

I do not know of any very definite evidence as to the age of the cappings in the North-Western Division of Western Australia.

The evidence in the north-eastern part of South Australia is not opposed to a similar age for the formation there. It rests upon beds which are Cretaceo-Eocene or Eocene, and which were already gently inclined before the era of peneplanation. The capping is of such antiquity as to have participated in some of the major earth movements involved in the formation of the Flinders Range and the Great Lakes Senkungsfeld. The deposits in the lake basins are very considerable in amount, and they contain fossils of vertebrate animals now extinct. While the upper portions of these lake beds are certainly Pleistocene, their deeper parts may be as old as Pliocene. These deposits are all newer than the Duricrust.

In Queensland, also, the Duricrust is developed over the surface of slightly disturbed Winton Beds, so that it is unlikely to be older than about Miocene.

Evidence as to the age of the "Desert Sandstone" in various places is, at least, not strongly opposed to the supposition of this age (Miocene) for the Duricrust.

If my contention is correct that the Duricrust constitutes a once-continuous formation of approximately Miocene age, it follows that this era must have been one of extraordinary crustal stability, in the western half of Australia at all events, to permit of the perfection of peneplanation requisite for the development of the chemical crust and its decomposed substratum. Conditions in eastern Australia need not have shown any marked sympathy, since, as Andrews has repeatedly pointed out, diastrophism has been progressively more recent as we pass from south-west to north-east. Even in eastern Australia, however, the great era of base-levelling which produced the continuous peneplain extending from northern Queensland to Tasmania must have been one of minimum diastrophism.

IS DURICRUST STILL FORMING?

The theory of the Duricrust indicates that the incidence of annual rainfall is an essential feature. The wide extent of the structure shows, therefore, that, at the date of its formation, the greater part of Australia possessed a climate marked by very decided alternations of saturation and desiccation. The fact that similar conditions still persist over the very regions characterised by the presence of the Duricrust might suggest that the chemically formed crust is less ancient than I have supposed, and that it is actually being produced over the area at present. That a certain amount of chemical precipitation is going on in the soil and subsoil in certain suitable areas is beyond cavil; but, I believe that such formation is local and relatively insignificant. It is quite distinct from the formation of the Duricrust proper.

Walther[15] believes that all the "laterite" is "fossil", and that it is not being produced anywhere at present. Blanck,[3] on the other hand, while admitting that much of the "laterite" is "fossil", holds that it is still forming, in places, even in Western Australia.

I have pointed out that, in the Darling Peneplain, the area has been epeirogenically uplifted to heights of about 1000 feet above sea level. The valleys thereby brought into existence have incised the borders of the plateau to such an extent as to institute highly perfect lateral drainage of the subsoil. Probably only a minute fraction of the soil moisture is now drawn to the surface by capillarity in the drainage areas of these young valleys. The mature valleys of the Meckering Level, while not so efficient in this respect, are also quite important drainage channels, probably quite competent to dispose of the greater part of the subsoil drainage of the area.

Wherever the drainage of the plateau is sufficiently sluggish, the amount of the rainfall adequate, and the bed-rocks within reach of the vertically moving solutions, "laterite" may continue to form; but I am not familiar with areas in which all these essential conditions prevail.

Where drainage channels cause a seepage of mineral waters along the valley sides, precipitation of "laterite" may occur, provided the requisite conditions of hydrogen-ion concentration are present. No doubt some such precipitation is taking place; but I have not observed it. Further, "laterite" produced in such situations will be distinguishable from Duricrust "laterite" since it bears a totally different relation to the zone of leached rock material.

Cementation of "laterite" talus at the feet of escarpments, and the existence of areas of low-level "laterite", let down from the main mass of step-faulting, introduce

complications. It is necessary to exercise considerable care lest such abnormal occurrences be mistaken for areas of "laterite" in process of formation at the present day.

Throughout the greater part of the interior of Australia the Duricrust remnants are in the form of comparatively small residuals capping mesas and buttes. In these circumstances lateral drainage is highly efficient. This fact, together with the absolutely small amount of the rainfall which now affects these regions, accounts for the absence of actively growing Duricrust there.

"TRAVERTINE."

Where strongly calcareous rocks are developed in areas with suitable climates there is a widespread formation of nodular travertine, like that so ubiquitous in South Australia. In and about Adelaide, for instance, the distribution of this substance proves that it is actively forming at the present time. Such calcareous crusts, however, are composed of the relatively soluble constituents of the rocks, and are only less easily removed and less temporary than are the efflorescences of alkaline salts and gypsum. I do not regard such travertine crusts, by themselves, as indications of the Duricrust. The much thicker crusts of such relatively insoluble substances as alumina, iron oxide and silica are in quite a different category. They require an enormously more protracted period for their development than does travertine, and, even if they are being produced at present, it is at an inappreciable rate.

It seems probable, then, that, while the formation of the crust may have continued for some time after the uplift of the peneplain, the dissection of the latter by erosion must have reduced progressively the area of active formation until, at present, crust formation is extremely subordinate.

"GIBBER PLAINS."

The former wide extension of the Duricrust is amply evidenced, particularly in Central Australia. Every traveller has been impressed by the enormous extent and the striking appearance of the "Gibber Plains" of the interior. The gibbers are undoubtedly the shattered fragments of the once-continuous Duricrust. As has been pointed out above, the combination of hard crust and soft, decomposed substratum produces an extremely weak structure. Once the continuity of the capping is broken, the soft base succumbs very rapidly to wind erosion. While I am inclined to think that Walther[15] has somewhat over-emphasized the importance of ablation as a factor in desert weathering, there can be no question as to its enormous efficiency in just that set of conditions developed owing to a break in the continuity of the Duricrust. Ablation removes only the fine material of the sub-stratum, and the surface of the "desert" areas becomes covered with a coat of mail, the "Panzerdecke" of Walther, consisting of a mosaic of Duricrust fragments, which effectively protects it from further erosion.

If the "Gibber Plains" be accepted as remnants of the Duricrust *almost in situ* the main difficulties in connection with the former continuity of the formation disappear.

POSSIBLE EXAMPLES OF DURICRUST.

Several important questions suggest themselves. Are there any other formations which belong to the Duricrust? What are its equivalents in eastern Australia, where uniformly distributed rainfall is now the rule? What is the explanation of "lateritic" formations possessing characteristics distinct from those of Western Australian "laterite"?

"UPLAND MIOCENE."

One formation which has given rise to much controversy is the Upland Miocene of South Australia, so named by Tate[20], in 1878. From my own limited personal acquaintance with this formation, I have little hesitation in claiming it as veritable Duricrust, albeit of somewhat aberrant type. The ferruginous capping in the neighbourhood of Gawler is, on the whole, very similar to that which is developed over the sandy Jurassic beds of the Irwin River in Western Australia, and still more like that capping a few small residuals of coarse sandstone near Bolgart in that State. The thoroughly typical "lateritic" crusts forming the surface of the Belair Level, near Adelaide, can be looked upon as nothing other than Duricrust. It is highly significant that these crusts are *"lateritic"* while the crusts at present forming on bedrocks of exactly the same kind about Adelaide are *travertine.* The present distribution of the remnants of the Upland Miocene agrees completely with the physiographic conditions postulated for the Duricrust. The Upland Miocene is universally held to be a terrestrial formation, and the determination of its age as Miocene is at least highly significant.

May we not regard the somewhat ferruginous surface of much of the Mount Lofty Plateau, with its substratum of highly decomposed arenaceous rocks, as of similar formation?

DURICRUST (?) IN SOUTH-EASTERN AUSTRALIA.

As mentioned above, there is no reason to suppose that the whole of eastern Australia shared in the widespread baselevelling which affected the western, and most stable part of the continent. Further, if the suggestion is correct that the *seasonal distribution* of rainfall has not been altered very considerably since the general limits of the continent were set, it may well be that one of the essential

conditions for duricrustal formation was very imperfectly developed in eastern Australia. In such circumstances, while we should look for the chemical criteria of peneplanation, we should expect those characteristics of uniformly distributed rainfall rather than definite Duricrust.

Without anticipating the full details of an investigation into the geological structure of the Blue Mountains, upon which I am engaged at present, I may state that I have found the conditions on the higher levels of these mountains almost identical with those of the Jurassic sandstones of Western Australia. In contrast with the solid outcrops of Hawkesbury Sandstone at the surface in the eastern zone of the mountains, the surface, about Blackheath for instance, is composed of hard ferruginous sandstone, resting upon quite incoherent, intensely white sandstone as much as 50 feet thick; but still absolutely *in situ*. The effects of successive leaching are here very apparent. In spite of some anomalies in the distribution of the "lateritic" ironstone in this area, to which I shall refer in detail in a future communication, the direct association of the three elements, superficial chemically formed ironstone, leached substratum and peneplain surface suggests that we have, even here, the equivalents of the more typical Duricrust of the western areas.

Within the limits of the suburbs of Sydney itself features, met with over the surface of typical Wianamatta Shale, suggest a similar interpretation. In most parts of the western and northern suburbs the soil is very shallow, and one soon encounters the heavy clay of the subsoil. In many places, however, very deep weathering of the shale is met with. Sections in railway cuttings like those near Chatswood and Wahroonga show striking analogies with those under typical "laterite" near Perth, but less perfectly developed. The very deep clay is leached nearly

free of iron, and is whitish in colour. Approaching the surface the clay becomes more mottled, and concretionary "ironstone" becomes abundant, until it forms a nearly continuous mass some six or twelve feet below the soil. Where excavations are lacking and the deeper portions of the section cannot be observed, the abundance of "ironstone gravel" at the surface indicated that the conditions well exhibited at Chatswood are widely developed. This is very notably the case over much of the south-western suburbs.

In a few cases there are developed veritable nodular "laterites" almost identical in appearance with those of Western Australia. This is so, for instance, at French's Forest and at Waterfall. Very similar "bauxites" are known to exist at many places on the uplands of New South Wales, as, for instance, at Wingello.

The occurrences at French's Forest and Waterfall would not be difficult to explain were it not that they are rather exceptional. If such nodular "laterites" were common they might be regarded as normal Duricrust; but it is difficult to account satisfactorily for their very sporadic distribution. Possibly there may be something in the immediately underlying rocks to account for the abnormally plentiful supply of oxides; but I think not. Possibly the suggestion advanced below to account for the Wingello bauxites may apply, in part. Otherwise I cannot account for them satisfactorily at present.

At Wingello and other places considerable masses of bauxite are developed in association with basalt and basalt tuff. The igneous rock is capable of supplying large quantities of iron and alumina, but the fact that bauxite occurs only very rarely, considering the abundance of basalt in New South Wales, indicates that special conditions are required for its formation. The bauxites do not occur, as does normal Duricrust, on the highest part of the

peneplain surface, but lie distinctly below that surface. In most if not all instances they are associated with *Tertiary leaf beds, and show evidence of having been deposited in small lake basins.* As pointed out in Part I such local basins must be expected to exist during the last stages of base-levelling. Basalt flows are notoriously porous structures. Traversed as they are by supercapillary openings, water passes through them freely, and capillarity is absent. This accounts for the well-known fact that many basalt plateaux, in spite of the richness of their soils, very rapidly respond to droughty conditions. The shallow basins lying around the basalt knolls, and kept supplied with water by reason of the percolation through the igneous rocks, may well contain sufficient amounts of dissolved organic matter to serve as precipitants for the amorphous metallic oxides. The occurrence of leaf beds in association suggests that the basins are swampy, a condition shown to be highly probable on the general surface of a peneplain of very high maturity. This condition of "sourness", then, may well be common to the formation of normal Duricrust, and of the less normal bauxites of the type under consideration.

ECONOMIC IMPORTANCE OF DURICRUST.

Certain possible economic resources of the Duricrust may be mentioned very briefly.

It is the source of the numerous deposits of precious opal which have been worked in Queensland, New South Wales and South Australia. There is no reason why many more such deposits should not be discovered.

The importance of the decomposed substratum as a source of water supply has been mentioned. The same decomposed material yields excellent fireclay in Western Australia. Search for clay deposits of various kinds may be facilitated

by attention to the evidences indicating prevalence of Duricrust conditions.

The hard material of the Duricrust is of considerable importance as a source of road metal; occurring, as it necessarily does, in regions where rock weathering is exceptionally deep, and where, consequently, both foundations and materials for roads are poor.

While, at present, no deposits are known of exploitable bauxite sufficiently pure to serve as aluminium ores, such deposits may be looked for. They may be anticipated either (1) as Duricrust covering rocks of *syenitic* facies, or (2) as freshwater deposits of the Wingello type, particularly in association with trachytic rocks.

Soils in typical Duricrust areas are necessarily stony and poor. The perfect leaching of the subsoil has removed almost everything in the way of plant food.

CONCLUSION.

The suggestion is made that, throughout almost the whole of Australia, in or about Miocene time, there existed a peneplain of almost ideal maturity of development.

Owing to the sluggishness of surface drainage resulting from such a structure, and accentuated by a markedly seasonal distribution of rainfall, relatively very deep-seated decomposition of rocks of all kinds and of all ages from Pre-Cambrian to Winton (Upper Cretaceous) occurred. The most soluble constituents, the alkalies, alkaline earths, magnesia and most of the iron were completely removed. Substances of intermediate solubility, including the balance of the iron, alumina and colloidal silica leached from the bed-rocks, became concentrated at or near the land surface. In some instances they formed beds of concretionary, chemically-formed rock, such as "laterite", "ironstone" or opal. In other cases, and especially where the subjacent

rocks were porous sediments, the chemically-formed material was precipitated in the guise of a dense cement, binding together the constituents of the porous rocks.

In every instance there is a relatively hard crust, resting upon a decomposed or weakened substratum of weathered rock material. For this crust, when it can be shown to have been formed during the great period of peneplanation, and under the conditions outlined above, I suggest the name of the DURICRUST. Extensive personal familiarity with the superficial formations of widely separated areas in Australia has led me to believe that this generalisation will help to remove many of the difficulties and apparent contradictions which have arisen, in the past, in connection with such widely distributed formations as the "laterite" of Western Australia, the "Upland Miocene" of South Australia, and the "Desert Sandstone" of Queensland, New South Wales and South Australia.

I am aware of the dangers involved in making use of lithological characters for correlation, and of the still greater pitfalls in the use of physiographic criteria; but I claim that the combined use of both criteria, together with careful consideration of all the features of the deposit, whether it rests on igneous rocks, crystalline schists as old as the Yilgarn Series of Western Australia, Permo-Carboniferous Glacial Beds, or Winton Beds, leads to a conclusion as to the unity of the formation which cannot fail to be of value to Australian Geology.

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THE OCCURRENCE OF A NUMBER OF VARIETIES OF EUCALYPTUS DIVES AS DETERMINED BY CHEMICAL ANALYSES OF THE ESSENTIAL OILS.

Part I.

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(With Plates I., II.)

(Read before the Royal Society of New South Wales, June 1, 1927.)

Eucalyptus dives Schauer, the common broad leaf peppermint, has long been of economic value for its essential oil, and is a species especially easy of botanical determination. The chemical composition of its essential oil has been shown to be remarkably constant, and its economic utilisation has depended upon its content of piperitone, usually 45-50%. Since the advent of its demand for the manufacture of synthetic thymol and menthol, a number of commercial samples of the oil have come under our notice, which on examination were found to be considerably below the standard demanded, the piperitone content varying from 5% to 30%. This fact was at first thought to be due to the distillers failing to continue the distillation sufficiently long to bring over the whole of the piperitone (see Bulletin No. 1 of the Technological Museum, Sydney, 1923, "The Detection and Estimation of Piperitone in Eucalyptus Oils"), or to admixture with other oils. Careful investigation, however, of the oils obtained from leaves personally collected, in conjunction

with field observations, soon showed that considerable variation existed in the composition of the essential oils from *Eucalyptus dives* growing in different centres. Although enormous tracts of country carry *E. dives,* the bulk of which yields an essential oil containing 45-50% piperitone, quite considerable areas have recently been observed, especially in parts of Victoria, where the trees yield an essential oil containing only from 5% to 15% of that constituent. (See Paper, 5th Congress of Industrial Chemistry, Paris, 1925, by A. R. P., published in "Chimie & Industrie", Vol. 16 (September, 1926), p. 555.)

The Braidwood district of New South Wales is famous for the constancy of the essential oil from *E. dives;* many hundreds of examinations of commercial samples and those of our own distillation have shown remarkably close agreement, the piperitone content being within the range 45-50%. During the latter part of 1925, samples of oil were received from this district containing less than 10% of the ketone. They were considered by the buyers to be grossly adulterated, or they represented only the first few hours distillate; consequently special samples were taken under police seal with a view to legal proceedings. On examination they were found to contain 8% piperitone. A special field investigation by one of us (A.R.P.) showed that the oil represented a pure full-time distillate obtained from trees which were undoubtedly *E. dives,* and apparently identical with the so-called Victorian type (see Table No. 2). Then again, whilst engaged in field service during the end of December, 1924, repairing a punctured tyre of the car by which we were travelling led us to examine a patch of trees of this species growing close to the Main Southern Road, about 18 miles on the Sydney side of Goulburn. The observation was made of two trees growing together, indistinguishable from one another by

both botanist and bushman, but each containing a different essential oil. On crushing the leaves between the fingers, one yielded the typical phellandrene-piperitone odour, whilst in the other the odour of cineol-phellandrene-terpineol was most pronounced (see Photograph No. 1). Leaf material was collected, and an examination of the oils obtained therefrom readily confirmed the field observations (see under respective tables for both Type and variety B). It was, therefore, apparent that several varieties or forms of *Eucalyptus dives* existed, distinguishable only by chemical means. We are perfectly satisfied that morphologically the trees are all undoubtedly *E. dives*, which opinion is founded not only on our own field observations, but upon careful determinations made by experienced botanists. A private communication from Mr. P. R. H. St. John, Botanic Gardens, South Yarra, Victoria, under date 8th April, 1926, is of special interest in this connection. It reads as follows:—

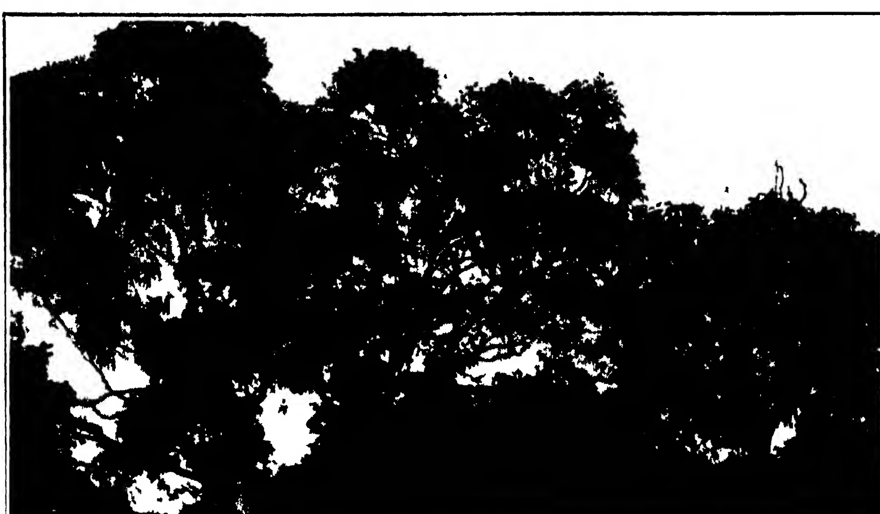
"During the last few days I had a chance to examine herbarium material of the New South Wales and Victorian forms of *Eucalyptus dives*. I tried every point to see if there is any morphological difference between these two forms, but failed to find one single character to distinguish these two trees. I compared all the material at the 'National Herbarium' also.

"Seedlings, young and matured foliage, buds and fruits, all agree with the other. I spent many hours over this examination that I might not miss any point."

During an inspection of the Goulburn district in August, 1926, we believed that slight differences in the trees could be detected, such as smaller fruit and black bark being characteristic of variety B (containing cineol), but the more extended the investigation, the more variable the characters became in all the various forms, until finally we could not confine them to any one variety or to the Type. In the course of this visit we were accompanied by Mr. F. Webb, of Braidwood, a very experienced bush-

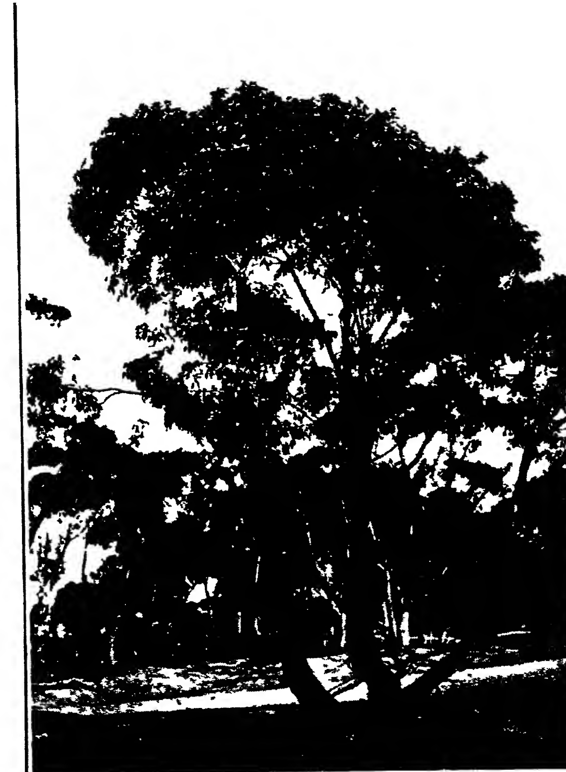
Photograph No. 1.

Trees of *Eucalyptus dives* growing adjacent to the Main Southern Road between Marulan and Goulburn, N.S.W. The clump of trees on the left yielded an oil containing 35-45% cineol and are thus identical with variety B, whilst those on the right contained one giving 42% piperitone, thus representing the Type.



Photograph No. 2.

Patch of trees of *E. dives* growing on the Main Southern Road between Marulan and Goulburn, N.S.W. It was possible to pick out three trees of variety B (containing cineol) and two trees of the Type containing 42% piperitone, by simply crushing the leaves in the hands.



Photographs Nos. 3 and 4.

Trees of *Eucalyptus dives* growing between Marulan and Goulburn, N.S.W. The one on the left is typical of the normal Type in this locality, whilst that on the right is a good specimen of variety B.

man and distiller, and although careful field tests were carried out on trees exhibiting variable chemical and botanical characters, yet it was impossible to distinguish the various forms except by crushing the leaves and noting the difference in the odours.

It has been known for quite a long time, although no data have been published, that a large percentage of the trees growing in Victoria yield oils low in piperitone content, about 5%, and in some cases a comparatively poor quantity of oil from the leaves. This variety for general business purposes has been known as the Victorian form. It is described herein under Table No. 2 as variety A. There also appear to be several intermediate forms between the type and this variety which yield oils containing from 18% to 36% piperitone, and it seems only reasonable to expect these transition forms.

During the years 1917 and 1918, material of *E. dives* collected at Merimbula, Batlow, and especially Tumbarumba, all in the southern district of New South Wales, yielded essential oils in good yield, approximating in composition to that of *E. Australiana,* in which piperitone could not be detected. Cineol was present to the extent of about 60%, with at most a trace of phellandrene, although very often this terpene could not be detected. At that time, in view of the fact that experienced botanists who had examined the material, not only in the herbarium, but in the field as well, reported that it was *E. dives,* it was considered desirable to record the results as a form of *E. dives.* The matter was deferred, however, pending more extensive experience with these forms. We are convinced now that this tree is a form of *E. dives,* and apparently the tree containing cineol observed in the Goulburn district, and now described as variety B, represents a transition stage between the Type *E. dives* and

this extreme form at Tumbarumba. The Forestry Department of this State, which renders the Institution much invaluable assistance in the collection of plant material, etc., has always forwarded the form referred to when requested to secure supplies of *E. dives* from Tumbarumba. In our opinion, the species described under *Eucalyptus Australiana* var. *latifolia* by Messrs. Baker and Smith in the second edition of "Eucalypts and Their Essential Oils", 1920, p. 174, is identical with this extreme form of *E. dives*. Their statement on page 175 of the publication referred to lends support to our contention:—

"Material for distillation was received from Officer, Victoria, in 1900, but as the results could not be specifically placed at that time, they were omitted in the first edition. On the discovery of *E. Australiana,* however, they fall into line and are now published."

The authors have examined trees growing at Moruya, New South Wales, and are satisfied that they cannot be distinguished from *E. dives* in the field. We have not yet, however, had an opportunity of examining the trees growing in Victoria or at Tumbarumba, but will do so as soon as a convenient opportunity presents itself; hence our decision to write further on the subject at a later date.

The variety A, although widely distributed throughout Victoria, has up to the present only been found in an area of any extent in one part of New South Wales, viz., at Spring-grove, Braidwood. The first deduction from this observation was to consider the variation in the Spring-grove material as due to ecological conditions, but this interpretation had to be rejected after our visit to Goulburn in 1926. Observation made there showed patches of trees wherein variety B was detected intermingled with trees of the normal type (see photograph No. 2). It was possible to pick out three trees of variety B (cineol, 30-/40%, piperitone, 14/18%) and two trees of the Type (42% piperitone).

There is an exceedingly large number of species of Eucalyptus, and we are reluctant to suggest any additions, and taking into consideration the fact that the trees yielding such variable oils are undoubtedly *E. dives* when examined in the field and on morphological grounds, we think it advisable to consider them as forms or varieties, until such time as future botanical research is able to deal with problems of this type. It seems only reasonable to expect these variations in chemical composition of oils from a tree like *E. dives,* which is probably a hybrid (the suggestion of Mr. E. Cheel, of the National Herbarium, Sydney), and we have detected these varieties in comparatively limited quantities in practically all fields of this species which we have examined. These observations are of considerable economic importance, and strongly support the contention set forth in Bulletin No. 4 of the Technological Museum, Sydney, 1925, "Guide to the Extraction of Eucalyptus Oil in the Field", p. 8, that where a distiller proposes to take up areas of *E. dives* for distillation, in order to secure an oil of high piperitone content it is necessary that average samples of leaf be taken from the proposed area for chemical investigation. This purpose can readily be achieved by a careful field inspection, since one experienced in the various odours of Eucalyptus oil constituents can readily differentiate the varieties from the Type by simply crushing the leaves in the hand.

We have been successful in raising seedlings, not only of the normal Type, but of the three varieties, and in each case they have, so far, bred true. The young seedlings from all four kinds were morphologically identical, yet when tiny fragments of the leaves, even from plants only 1½ inches in height, were rubbed between the fingers, the characteristic odour of each particular kind was readily detected. The seedlings could be mixed, and yet readily

sorted out again by means of the test described. A selection of the seedlings has been planted out, and when old enough for cutting, the leaves will be distilled and the essential oils therefrom examined and the data published.

Summary.—As a result of our investigations, we are of the opinion that, allowing for the various intermediate forms, three distinct varieties of *E. dives* exist, apart from the Type. They are as follows:—

E. dives, Type. Essential oil contains piperitone, 40-50%; phellandrene, 40%.

E. dives, var. A. Essential oil contains piperitone, 5-15%; phellandrene, 60-80%; piperitol.

E. dives, var. B. Essential oil contains piperitone, 10-20%; cineol, 25-50%; together with phellandrene.

E. dives, var. C. Essential oil contains cineol, 45-75%; piperitone, under 5%; phellandrene absent, or present in small quantity only.

Only the Type and the variety C are of commercial importance. A small quantity of the latter finds its way to the market from the Tumbarumba district, but the quality varies considerably. (See under special heading and Table No. 4.)

The information detailed in this paper is based upon chemical data and careful field observations recorded by chemists, but at the same time we wish to make it clear that we have freely discussed the problems with our botanical friends, who have evinced great interest in the observations, with the result that we think our deductions are free from chemical bias. In this connection, we wish to record our appreciation of the kindly criticism and advice we have received from Mr. E. Cheel, Curator of the National Herbarium, Botanic Gardens, Sydney, in con-

nection with the many interesting, but apparently complicated botanical-chemical problems arising in the study of Australian native flora. It would have been quite impossible to have brought forward these interesting observations regarding *Eucalyptus dives* unless there had been free and frank discussion and co-operation between representatives of both botany and chemistry.

Our thanks are also due to many other friends, who have not only kindly forwarded supplies of leaves, but have very courteously rendered invaluable assistance when engaged in field work. Mr. A. J. Bedwell, of 822 George Street, Sydney, is deserving of special mention, as when unable personally to accompany the authors, he kindly placed his field manager, Mr. F. Webb, and motor car at their disposal. We also wish to express our thanks to Mr. P. R. H. St. John, of the Botanic Gardens, Melbourne, for kindly forwarding a sample of oil distilled by himself from leaves of variety A.

EXPERIMENTAL.

The many collections of leaves and terminal branchlets which have been examined are set forth in the following Tables, Nos. 1 to 4 inclusive, the Type and various varieties being separately shown. The chemical and physical characters provide a striking line of demarcation of the various forms.

Eucalyptus dives Normal Type (see Table No. 1).

Very little additional information need be written under this head as Table No. 1 furnishes confirmation of what has previously been published concerning this species. Much of the additional data furnished was obtained in conjunction with a study of varieties A and B, the material in many instances being collected at the same time and under identical conditions. For example, the sucker leaves

collected at Bombay, Braidwood, 19/7/1926, were obtained under similar conditions on the same day as the sucker leaves of variety A, collected at Spring-grove, Braidwood. The chemical composition has been confirmed, as approximately *l*-*a*-phellandrene, 40% and *1*-piperitone, 45-50%.

Eucalyptus dives Variety A (see Table No. 2.)

The essential oil of this variety possesses a distinctive odour of piperitol, and much resembles that of *E. radiata.* The constituents, so far identified, are *l*-*a*-phellandrene, about 60%, varying up to 80%, piperitone, 2 to 8%, and the alcohol, piperitol.

The comparatively high content of piperitol is a characteristic feature of the oil, and it is this constituent which renders the variety easy of determination. An interesting observation was made in connection with the variable yield of oil obtained from leaves collected at Spring-grove, Braidwood, in July, 1926. Some of the trees possessed foliage of a bright green colour, whilst others were of a glaucous (bluish) character. Leaves were collected at the same time and place, in fact the trees were growing alongside of one another, the cut being identical in both instances, yet the former yielded 4.12% and the latter 3.2% of oil.

Eucalyptus dives Variety B (see Table No. 3).

This variety yields an essential oil containing *l*-*a*-phellandrene, cineol, 25-45%, piperitone, 10-20%, together with piperitol, terpineol, and geraniol. Citral is also present in small quantity, about 1%.

The identification of this variety, although itself of negligible value, is of considerable importance from the economic aspect, when its relationship to the type *E. dives* is considered. Very often tests made on small lots of leaves and terminal branchlets of *E. dives* from certain

areas of country showed a piperitone content of the oil of 48-50%, yet commercial distillations have yielded lower percentages of the ketone, together with the presence of excess of cineol. The admixture of this variety with the Type, which could not well be avoided by the distillers, would readily account for the discrepancy.

Eucalyptus dives Variety C (see Table No. 4).

The chemical and physical constants are set forth in Table No. 4. This most interesting and variable oil is practically water-white in colour, and possesses all the physical, and in fact chemical, characters of *Eucalyptus Australiana.* The principal constituents so far identified are cineol (usually, 60-70%), piperitone, traces up to 6%, terpineol and its esters, geraniol, sesquiterpene, *l* α-phellandrene and citral. The oil is distilled in fair quantities principally at Tumbarumba, New South Wales, but in our opinion is a very "tricky" species to handle commercially, as it may be quite free from phellandrene on one occasion, and on another contain sufficient of this terpene to condemn it for sale as a pharmaceutical oil. The time of year, the particular area being worked over, and the variation in the individual trees, all result in considerable differences in both the cineol and phellandrene content of the oil.

Quite recently an instance was brought under our notice which provided strong confirmatory evidence in support of the above remarks. A consignment forwarded to London was assayed by a well-known firm of essential oil analysts, who sampled several tins with the following variable results:—

(a) Cineol Content, 52%, phellandrene, positive.

(b) Cineol Content, 72%, phellandrene, negative.

TABLE No. 1. *EUCALYPTUS DIVES*. TYPE

Date.	Locality.	Yield of Oil. %	d_{15}^{15}	a_D^{20}	n_D^{20}	Solubility in 70% Alcohol.	Piperitone Content	Cineol Content.	Phellandrene.	Ester No. 1½ hours hot sap.	Ester No. after Acetylation.	Remarks.
13/7/23	Sunny Corner Wallerawang, N.S.W.	2.7	0.9043	−61.7°	1.4810	1.6 vols.	53%	...	...	..	...	
18/7/25	Portland, N.S.W.	3.1	0.9063	−58°	1.4788	1.4	53%	...	...	...	...	
13/3/25	A. J. Bedwell, Grant's Still, Braidwood, N.S.W.	5.4	0.9004	−61.65°	1.4794	1.3	50%	...	..	.	.	High yield of oil due to dry condition of leaves.
19/7/26	A. R. Penfold, Bombay, Braidwood.	3.2	0.8938	−78.5°	1.4790	10	46%	...	...	...	...	"Sucker" leaves
31/8/26	Penfold and Morrison, 18 mile peg from Goulburn.	2.3	0.8920	−72°	1.4802	Insol. 10 vols.	42%	.	...	.	...	
1/9/26	A. E. Coleman, Adjungbilly, via Bookham, N.S.W.	3.1	0.8961	−68.3°	1.4802	do.	46%	...	...	...	...	Leaves comparatively narrow and fruit small.

TABLE No. 2 *EUCALYPTUS DIVES* VARIETY A.

Date	Locality	Yield of Oil %	d_{15}^{15}	α_D^{20}	n_D^{20}	Solubility in 70% Alcohol.	Piperitone Content	Cineol Content	Phellandrene	Ester No 1½ hours hot sap	Ester No after Acetylation	Remarks
3/3/24	W.K.Burnside & Co., Melb.	5.1	0.8684	−61.4°	1.4779	Insol. 10 vols	5%		...	..	...	
12/8/25	A. J. Bedwell, Spring Grove, Braidwood	3.65	0.8720	−56°	1.4784	do.	2%	...	...	16.3	72	
26/2/26	P.R H St.John Melbourne, (Macedon district)	1.5	0.8683	−43.75°	1.4777	do.	3%	. .	...	8.2	55	Average mixture of young and mature foliage. Sucker leaves, "green" colour.
19/7/26	A. R Penfold Spring Grove, Braidwood	4.12	0.8751	−69.9°	1.4750	do.	nil.	.	.	12.6	99	
do.	do	3.2	0.8771	−63.9°	1.4759	do	nil.	..	..	6.0	81	do. glaucous (blue)

Commercial Samples of Oil

Date	Locality	Yield of Oil %	d_{15}^{15}	α_D^{20}	n_D^{20}	Solubility in 70% Alcohol.	Piperitone Content	Cineol Content	Phellandrene	Ester No 1½ hours hot sap	Ester No after Acetylation	Remarks
7/9/25	From W K. Burnside&Co. Melbourne.		0.8647	−60.3°	1.4783	.	6%		.			
Nov. 25	Samples under Police Seal from Braidwood (3 in all)		0.8630	−63° to −66°	1.4792		8%					

TABLE No 3. *EUCALYPTUS DIVES*, VARIETY B.

Date.	Locality	Yield of Oil. %	$d\frac{15}{15}$	α_D^{20}	n_D^{20}	Solubility in 70% Alcohol.	Pipertone Content.	Cineol Content.	Phellandrene	Ester No 1½ hours hot sap.	Ester No after Acetylation	Remarks.
28/12/24	Penfold and Morrison, 18 mile peg, Main Southern-road Goulburn, N.S.W.	3.4	0.9144	−15.6°	1.4669	1.1	12%	45%	present in quantity	...		
31/8/26	do.	3.4	0.9062	−28.3°	1 4711	1.3	18%	25%	do.	52	123	
do.	do.	2.9	0.9110	−21.5°	1.4685	1.2	14%	30%	do	55	116	
do.	do.	3.9	0.9148	−13.4°	1.4680	1.1	14%	35%	do	46	100	"Sucker" leaves

TABLE No. 4. *EUCALYPTUS DIVES*, VARIETY C

17/4/17	E. Cheel and A. R. Penfold, Merimbula, N S.W.	2.4	0.9160		..	.	...	60%	not detected	...	...	
30/3/18	Tumbarumba, N.S.W.	2.3	0.9190	+4 1°	..	.	...	60%	do	15.7 (acid No2)	67.45	
28/6/18	do.	2.7	0.9214	+2.2°	.	..	..	64%	do.	11.1 (acid No1)	42.44	
8/10/18	do	2.4	0.9214	nil.			..	72%	trace only	...	...	"Sucker" leaves.
31/8/25	McGrath, Tumbarumba	4.2	0.9236	+3.1°	1.4635	1.0 vol.	..	63%	not detected	...	...	
19/8/26	District Forester, Tumbarumba	2.0	0.9212	+8.1°	1.4742	1.4 vols	2%	25/30%	trace only	14 7	86.6	
21/8/26	Geo Blomley. Tumbarumba.	2.0	0.9153	+1.35°	1,4678	1.2 vols.	6%	45%	do.	21.4	73.6	

TABLE No. 5 *EUCALYPTUS DIVES* (form intermediate between Type and Variety A).

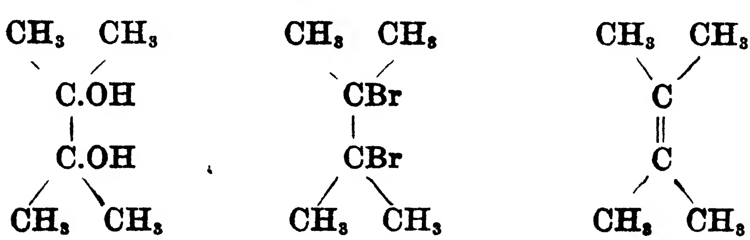
Date	Locality	Yield of Oil %	$d\frac{15}{15}$	a^{20}_{D}	n^{20}_{D}	Solubility in 70% Alcohol	Piperitone Content	Cineol Content.	Phellandrene	Ester No 1¼ hours hot sap	Ester No after Acetylation	Remarks
3/9/24	W.K.Burnside & Co. (2% on wt. when freshly cut) Melbourne.	3.0	0.8896	−56.8°	1.4786	1.6 vols.	26%	.	...	56 14	104	
27/4/25	N.E. Victoria	2.9	0.8866	−68.7°	1.4784	10 vols	36%		.			
12/8/25	A. J. Bedwell, Spring Grove, Braidwood.	3.3	0.8918	−52.5	1.4803	9 vols	33%			.		
4/6/26	W.K. Burnside & Co., Benalla, Victoria.	2.1	0.8934	−57 5°	1.4793	9 vols.	32%		..	..	...	

THE PREPARATION OF TETRAMETHYLETHYLENE.

By J. C. EARL, D.Sc., Ph.D.

(Read before the Royal Society of New South Wales, June 1, 1927.)

In connection with investigations into the chemical behaviour of nitrosochlorides, the preparation of a supply of tetramethylethylene had to be undertaken. At first, the method followed was that advocated by Thiele (Berichte 1894, **27**, 454), starting with acetone, from which pinacone (I) is obtained by reduction in an alkaline medium. The hydroxyl groups in pinacone may be replaced by bromine by the prolonged action of an aqueous solution of hydrobromic acid, saturated at 0°. The resulting dibromide (II) suffers loss of bromine when it is dissolved in glacial acetic acid and treated with zinc dust, and yields tetramethylethylene (III).



I II III

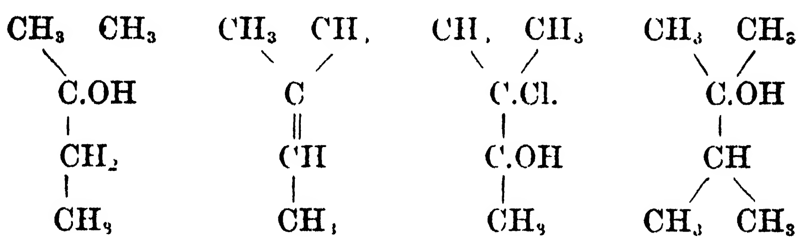
While the above reactions were successfully put into operation, it was found that their use as a process for the preparation of quantities of the hydrocarbon involved certain practical disadvantages. In the first place, although improved methods for the preparation of pinacone were employed (Richard and Langlais, Bull. Soc. Chim., 1910,

[4], **8**, 456; Adams, Organic Syntheses, Vol. V, p. 87), each of them demanded much manipulation and considerable expenditure of time. Further, in the following stage, the employment of a relatively large amount of hydrobromic acid saturated at 0° was necessary, and this reagent had to be prepared by saturating the acid of constant boiling point with gaseous hydrobromic acid. The production of the dibromide was therefore carried out on a small scale only, the hydrobromic acid being recovered and re-saturated after each experiment. This placed a limitation also on the scale on which the final stage of the process could be carried out, since the tendency of the dibromide to undergo change on keeping rendered it desirable to debrominate it as soon as possible after preparation.

A search of the literature revealed that an alternative series of reactions was available, leading to the formation of tetramethylethylene. Some of these reactions have not been described with any great degree of experimental detail, and apparently they have not been correlated hitherto as successive stages in a process for the preparation of tetramethylethylene. The product known commercially as amylene hydrate, and more scientifically as dimethylethylcarbinol (IV), furnishes the raw material. By dehydration with crystalline oxalic acid this substance yields the unsaturated hydrocarbon, trimethylethylene (V) (D.R.P., 66, 866; Friedländer, Fortschritte der Teerfarbenfabrikation, **3**, 980). The chlorohydrin (VI) of this hydrocarbon can be prepared in the usual way by the action of hypochlorous acid upon it. From the chlorohydrin, by the action of magnesium methyl iodide, Henry (Comptes rendus, 1907, **144**, 311) obtained dimethyl*iso*propylcarbinol (VII). This alcohol is readily dehydrated by dilute sulphuric acid (Delacre, Bull. Soc.

Chim., 1906, [3], **35**, 814), but a concentrated solution of oxalic acid is equally effective.

All the above reactions were carried out with great ease, and it was possible to interrupt the series at any stage without deterioration of the material. The quantitative aspect was also satisfactory, since from 100 g. of amylene hydrate, 66 g. of trimethylethylene, 38 g. of the chlorohydrin, 18 g. of dimethyl*iso*propylcarbinol and 11 g. of tetramethylethylene were obtained in the successive operations. For comparison, it may be stated that, for the preparation of the same quantity of the hydrocarbon by Thiele's method, 80 g. of pinacone hydrate and 400 c.c. of hydrobromic acid saturated at 0° were required.



IV V VI VII

EXPERIMENTAL.

Preparation of Trimethylethylene.

The procedure adopted was substantially that of the continuous method described in D.R.P., 66,866, except that the vapours issuing from the reaction flask were passed through a fractionating column, at the top of which the temperature was not allowed to exceed 45°, while the contents of the flask were maintained at about 90°. The weight of hydrocarbon obtained from 100 g. of amylene hydrate was 66 g.

The Preparation of Trimethylethylene Chlorohydrin.

Chlorine was passed into a vigorously stirred mixture of water (2 litres) and calcium carbonate (50 g.) until

an increase in weight of 44 g. had been obtained. After filtration, the solution of hypochlorous acid so formed was shaken or stirred thoroughly with trimethylethylene (33 g.) for some hours, until the hydrocarbon had been completely absorbed. The chlorohydrin was isolated by extraction with ether and subsequent distillation, using a rod and disc column, the fraction (19 g.) distilling between 139° and 144° being collected.

The Preparation of Dimethylisopropylcarbinol.

Magnesium methyl iodide was prepared in the usual way by the interaction of magnesium (13 g.) and methyl iodide (79 g.) in the presence of dry ether (190 c.c.). When the reaction had been brought to completion, the resulting mixture was cooled in ice and a solution of the chlorohydrin (22.5 g.) in dry ether (40 c.c.) gradually introduced during a period of 40 minutes. After removal of the ether, the residue was decomposed with water and submitted to steam distillation. The distillate, after being mixed with a quantity of potassium carbonate, was extracted with ether and the ethereal solution dried over potassium carbonate. The solvent was evaporated off, and the residue distilled using a column, the dimethyl*iso*propylcarbinol (10.8 g.) being collected between 115° and 125°.

The Dehydration of Dimethylisopropylcarbinol

A solution of oxalic acid (20 g.) in water (40 c.c.) was heated just to boiling in a flask fitted with a dropping funnel and a rod and disc fractionating column. Dimethyl*iso*propylcarbinol (10.8 g.) was gradually introduced, the rate of addition being so controlled that the temperature at the top of the column did not exceed 80°. After all the dimethyl*iso*propylcarbinol had been added, the distillation was continued until no further distillate passed over below 80°. The distillate consisted of almost pure

tetramethylethylene (7.0 g.) with a little water. Further purification of the hydrocarbon was not necessary, since it readily gave the solid blue nitrosochloride in good yield when allowed to react with nitrosyl chloride.

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PROTOGENESIS AND EX-NUPTIAL NATALITY IN AUSTRALIA.

By Sir George H. Knibbs, C.M.G., M.I.Inst.deStat., Hon. F.S.S., Hon. M. Amer. Stat. Assoc., Hon. M. Stat. Soc. Hungary, etc.

(Read before the Royal Society of New South Wales, June 1, 1927.)

Synopsis.—1, Significance of the questions considered. 2, The procreative impulse. 3, Ex-nuptial births. 4, Relation of ex-nuptial births to births occurring within nine months of marriage. 5, Frequency of ex-nuptial births according to age of mothers. 6, Initial and terminal frequency of ex-nuptial births. 7, Initial and terminal frequencies of ex-nuptial and nuptial births compared. 8, Significance of protogenesic phenomena. 8a, Masculinity of first-births. 9, Two classes of first-births. 10, Relative number of first-births according to all durations of marriage. 11, Change in age-constitution of married women. 12, Relative protogenesic fertility of women of different ages. 13, Percentages of first-births born within nine months of marriage. 14, Pre-nuptial insemination according to the age of mothers. 15, Change of the frequency of pre-nuptial insemination with the lapse of time. 16, Variation of fertility with age and time. 17, The effective gonad urge. 18, Age and measurement of the maximum intensity of the gonad urge. 19, The probability of ex-nuptial maternity. 20, Number of mothers as related to the numbers of children. 21, Points for further study. 22, Conclusions.

1. *Significance of the questions considered.*—The analysis as regards the phenomena of population development, of census data, and of general statistical results, is of a value to human biology that yearly is becoming increasingly manifest. As at present constituted, the social organism is the theatre of a conflict between controls and traditions (which are generally supposed to be of great social interest and value) and the gonad urges of the individual human organisms. Biological facts, which throw any light upon

the features and trends of this conflict, have been at all times of scientific importance. Owing to the advance of knowledge in respect to the functioning of the endocrine and sex glands, and in respect to the technique of the control of their unrestricted play, the analysis of facts which reveal the features and drift of this conflict has become, quite recently, of very special importance. And certain aspects of this are accentuated in significance by existing and threatening difficulties arising from population-growth. These difficulties are world-wide.

The data used will generally be found in the statistical publications of the Bureau of Census and Statistics of the Australian Commonwealth. As these are widely accessible, the analytic tabulations made from them will as a rule alone be given, as the compilations and tabulations therefrom can readily be checked, where thought necessary. Much elaborate tabulation is in this way avoided, and the material here given is thus restricted to what is essential in establishing the phenomena discussed or revealed, and analysed.

References to authorities quoted will be made as brief as possible.

2. *The procreative impulse.*—In human populations, the procreative impulse, due to the gonad urge, is modified by beliefs and traditions, by social controls, and by some measure of the sense of responsibility. The challenge of control of all kinds is most forcibly exhibited by two phenomena: (i) births outside the state of marriage, *i.e.*, ex-nuptial births; and (ii) births occurring within the period of nine months after marriage, *i.e.*, births mainly due to pre-nuptial insemination. The force of the procreative impulse is also shown to some extent (iii) by the measure of reproductivity generally: this, however, is perhaps more limited by economic considerations and

social traditions. The fertility of women of the child-bearing ages, giving birth to children, after a normal interval from the date of marriage, may be assumed to be probably less prejudiced by considerations of family limitation than afterwards. We shall commence with the consideration of ex-nuptial births.

3. *Ex-nuptial births.*—The simplest method of considering the characteristic place which these occupy in the life of a community is to ascertain the ratio that they bear to the total number of births in the same period This information is available for the States of New South Wales and Victoria, combined, from 1876 to 1925 inclusive—50 years; and is as shown in the following table, which gives also the results for the whole of Australia from 1901 onwards:

Table I.—Percentages of ex-nuptial on total Births for New South Wales and Victoria, 1876 to 1925, and for Australia, from 1901 to 1925; and smoothed results.

New South Wales and Victoria; 1876 to 1925.

Year	Ratio%	Smoothd.	Year	Ratio%	Smoothd.	Year	Ratio%	Smoothd.
1876	3.84	3.84	3	5.86	5.77	1910	6 00	6.15
7	4.01	3.95	4	5.91	5.91	1	6.07	5.97
8	4.09	4.28	5	5.96	6.03	2	5.65	5.58
9	4.69	4.62	6	6.19	6.13	3	5.63	5.63
1880	4.57	4.69	7	6.05	6 22	4	5.41	5.41
1	4.71	4.64	8	6.19	6.31	5	5.28	5.18
2	4.49	4.49	9	6.39	6.39	6	4.89	4.95
3	4.44	4.37	1900	6.56	6.47	7	5.04	5 15
4	4.35	4.44	1	6 45	6.38	8	5.44	5 44
5	4.49	4.49	2	6.11	6.19	9	5.39	5 39
6	4.70	4.64	3	6.27	6.25	1920	4.97	5.07
7	4.68	4.79	4	6.52	6.52	1	4.84	4.81
8	4.95	4.94	5	6.61	6.57	2	4.67	4.75
9	5.15	5.09	6	6.41	6 41	3	4.75	4.73
1890	5.18	5.24	7	6.37	6.37	4	4.74	4.74
1	5.23	5.42	8	6 36	6.33	5	4.76	4.76
2	5.66	5.61	9	6.23	6.23			

Australia; 1901 to 1925.

1901	5.99	5.87	1910	5.75	5 86	9	5.30	4.86
2	5.82	5.97	1	5.79	5.72	1920	4.84	4.79
3	6.01	6.06	2	5.53	5.58	1	4.75	4.72
4	6.17	6.15	3	5.48	5.45	2	4.49	4.67
5	6.24	6.21	4	5.26	5.33	3	4.61	4.63
6	6.23	6.22	5	5.12	5.22	4	4.62	4.61
7	6.15	6.19	6	4.77	5.11	5	4.64	4.63
8	6.16	6.11	7	4.91	5.02			
9	6.01	5.99	8	5.23	4.94			

The table gives the percentages, found by dividing the sums of the ex-nuptial births of the two States by the sums of the total births of the two States.* Analogously for the whole of Australia from 1901 onwards.*

The graph of the results of the above tables is shown on Fig. 1 (see curve A); the round dots denote the crude results, and the firm line the smoothed ones, that is for the two States. For Australia, the broken line, curve B, gives the smoothed results only. The curve A does not conform to any simple formula, but suggests a sine curve of perhaps 60 or 70 years period, with an amplitude of, say, 3 per cent., superimposed upon which curve are several lesser fluctuations. Observations for a longer period than 50 years are necessary to ascertain whether this surmise is really a correct one.

So far as we are aware, no physical or economic phenomena exist which throw any light upon this increase of ex-nuptiality of births, for the long period of thirty years at least, nor is it easy to account for its diminution from 1905 onwards.

The curve B for Australia, of course, exhibits the same general trend as curve A, and it may be observed that the smoothed curve does not show the oscillation which actually exists, similarly to curve A. (See the values in the table.)

4. *Relation of ex-nuptial births to births occurring within nine months of marriage.*—It might be thought that the two classes of births, which presumably are marked expressions of the force of the gonad urge against the elements which aim at controlling it, would exhibit some very definite correlation. In table II, hereunder, are shown the following, viz.:—Line (i) years covered; line

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* As given in the respective State and Commonwealth publications.

(ii) the percentage of all nuptial first-confinements (not births), which occur within nine months of marriage (this will be very approximately the same as the percentage of first-births); line (iii) the percentage ratios to all births of those which are ex-nuptial; line (iv) shows the ratio between these two percentages.

Table II.—Percentages (ii) of nuptial first-Births which occur within nine Months of Marriage; Percentage (iii) to all Births of those which are ex-nuptial, and the ratios (iv) of these percentages. Australia, 1908 to 1925.

(i)	1908	1909	1910	1911	1912	1913	1914	1915	1916
(ii)	33.81	34.64	35.52	36.39	35.76	34.39	33.47	33.73	30.33
(iii)	6.16	6.01	5.75	5.79	5.53	5.48	5.26	5.12	4.77
(iv)	5.49	5.76	6.18	6.28	6.47	6.28	6.36	6.59	6.36

(i)	1917	1918	1919	1920	1921	1922	1923	1924	1925
(ii)	27.91	29.57	31.60	29.83	30.34	29.22	29.52	29.75	30.40
(iii)	4.91	5.23	5.30	4.84	4.75	4.49	4.61	4.62	4.64
(iv)	5.68	5.65	5.96	6.16	6.39	6.51	6.40	6.44	6.55

These figures give, for the arithmetic means of the first nine results, respectively, 34.227, 5.541, and 6.177 (or mean 6.197); and for the second nine, 29.793, 4.821, and 6.179 (or mean 6.193); and for the whole eighteen, 32.010, 5.181, and 6.178 (or mean 6.195). It is seen that, though both percentages were appreciably less for the second nine years, the ratios of the arithmetic means remained almost identical. Such a fact suggested that the question should be further examined as to whether the two phenomena were really closely related.

Curve C on Fig I is the graph of the figures in line (ii) of table II, and Curve D (with a different zero) is the graph of line (iii). Curve E is the graph of line (iv): it shows very clearly that the ratio between curves (ii) and (iii) is very variable and follows no simple law.

It will be noticed that the numbers, born within nine months of marriage, are a large proportion of all first-births, averaging 32 per cent. for the last eighteen years;

on the average they were 57.32 per cent. of those born in the first twelve months after marriage in 1907-14, and 55.42 per cent. in 1915-25. In the following table (III) further data will be given, for examining the question from 1908 to 1925:

Table III.—Mothers of Children born within nine Months of Marriage (A-N), and ex-nuptial Mothers (E-N), and the Ratios between them. Australia, 1908-25.

Year	A-N	E-N	Ratio	Year	A-N	E-N	Ratio	Year	A-N	E-N	Ratio
1908	8691	6769	780	1914	12245	7199	588	1920	11861	6547	552
9	9494	6808	717	5	12000	6854	571	1	12445	6401	514
10	10021	6669	666	6	10420	6226	598	2	11183	6122	547
1	11282	7018	622	7	8564	6321	788	3	10947	6229	569
2	12404	7299	588	8	8344	6526	782	4	10961	6192	565
3	12525	7380	589	9	9102	6421	705	5	11255	6262	556
Totals	64417	41943	6511		60675	39547	6518		68652	37753	5499

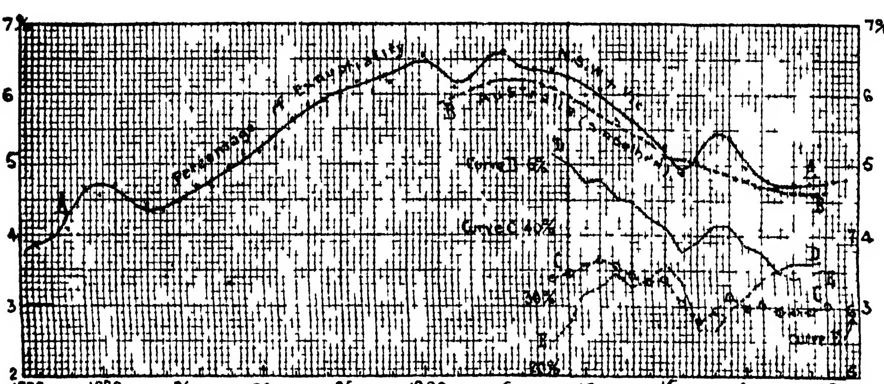

Fig. 1.

Curve A:—The dots denote the percentages of births in New South Wales and Victoria, taken together, which are ex-nuptial. The line denotes their general trend.

Curve B:—Denotes, in a similar way, the general trend for the whole of Australia.

Curve C:—The dots, surrounded by circles, denote the percentages of nuptial first-births occurring within nine months of marriage.

Curve D:—Denotes the percentage of all-births, which are ex-nuptial.

Curve E:—Denotes the ratios of the values in Curve C to those in Curve D.

The totals over all are 193744 and 119243, the ratio of the latter to the former being 0.61546. The respective numbers are shown by graphs, Fig. 2, the curve of births, before nine months after marriage, by broken lines (1), and of ex-nuptial births by firm lines (2). The oscillation about the mean position in the case of (1) is very large and irregular; in the case of (2) is smaller but also irre-

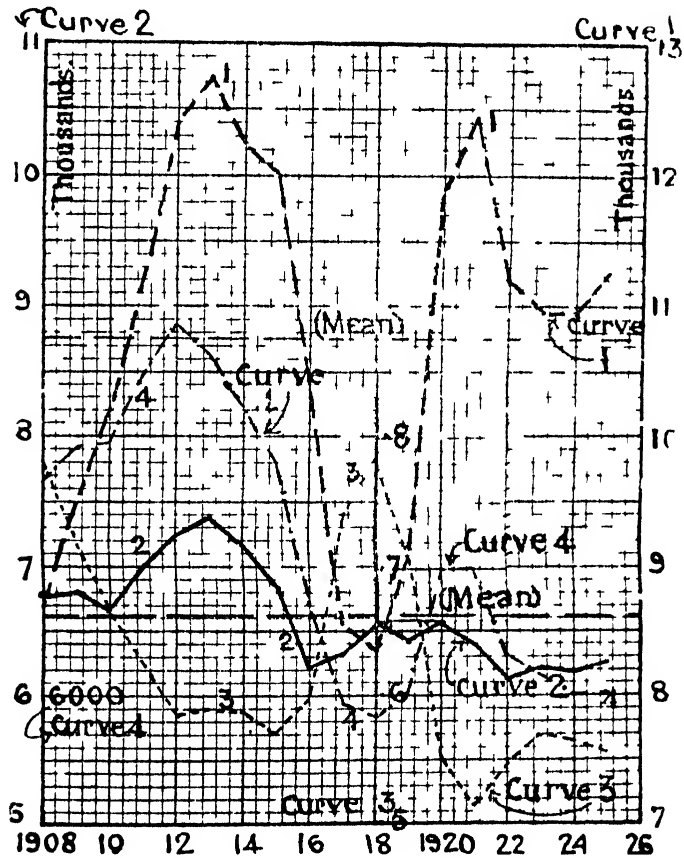

Fig. 2.

Curve 1.—Annual number of mothers giving birth to children within nine months of marriage.

Curve 2.—Annual number of ex-nuptial mothers.

Curve 3.—Ratio of numbers in Curve 2 to those in Curve 1.

Curve 4.—Numbers, per million females in the population of Australia, annually giving birth to children ex-nuptially, or within nine months of marriage.

gular. (The zeros of the two curves are not identical.) The degree of correlation between the two, at first glance, would seem insignificant. The ratios show, for example, *that no simple functional relation exists between the two results. Apparently the variations with time have no common term; and at first* the phenomena seem to be independent. This is more evident from the graph of the ratios, shown by the fine dotted line on Fig. 2, curve (3). But this last, however, shows clearly that, when the number of births before nine months after marriage is large, the ratio is small. Analysis, however, proved that between the ratios in table III, or their reciprocals, there was no simple relation. In other words, if we wrote $e_t + kf(t) = C$, in which e_t was the number of ex-nuptial mothers in the date year t, and k and C were constants, the function, $f(t)$, will neither be simple nor significant. For this reason, the view that mothers who give birth to children before nine months from marriage may appropriately be placed in the same category as mothers who furnish ex-nuptial births, is evidently statistically invalid. If we combine the two classes, and ascertain the number per million females (of all ages) in the population, we get the results in the following table:—

Table IV.—Annual number, per million Females in the whole Population, of ex-nuptial Mothers, together with Mothers giving Birth within nine months of Marriage. Australia, 1908 to 1925.

Years	Numbers per million					
1908-13	7658	7919	7935	8484	8851	8639
1914-19	8217	7792	6763	5948	5845	6008
1920-25	6993	7021	6322	6153	6027	6035

The graph of these is shown as Curve (4) on Fig. 2. It is immediately evident that it is no simple function of time.

From what has been shown, it is clear that births occurring within nine months of marriage, and ex-nuptial births, should be regarded as independent socio-biological phenomena. *They do not combine to form a homogeneous group.* They will consequently be considered separately.

5. *Frequency of ex-nuptial births according to age of mothers.*—The crude rate of ex-nuptial maternity per annum was given by us earlier for every year of age from 12 to 53 (see Math. Theory of Population, p. 242). In order to ascertain the characteristics of the change in the rates of ex-nuptiality of births, between the Census of 1911 and that of 1921, it will be quite sufficient to take these rates out for five-year age-groups. These are shown in Table V hereinafter. The numbers of ex-nuptial cases, on which the rates depend, are the means of the age-group results for five years, viz., for the census-years and two years before, and two years after such years. This minimises the effects of any small variations from the verage, of the census-year itself, and gives a better indication of the course of the change. In every group, from age 15 to age 49, it will be seen that the rate has fallen. For 683,925 unmarried* women in 1911 there were only 6,947 ex-nuptial births, or 1,015.8 per 100,000; while for 749,965 unmarried women in 1921, this number had fallen to 6,280, or 837.7 per 100,000; that is, to only 0.8247 of the rate in 1911. This is due to the diminution of ex-nuptiality of births, *mainly among women of ages 15 to 29.* The following table shows the changes more clearly:—

*That is, women "never married": it does not include widowed and divorced women.

Table V.—Changes of Ex-nuptiality of Births for five-year Age-groups from 12 to 49 years of age, between 1911 and 1921, Australia.

	1911			1921			
Age-group	U.wom.	Births	Rate	U wom.	Births	Rate	Ratio
12-14	126,255	18	14	152,351	27	18	1.3
15-19	214,635	1,864	868	219,348	1,580	720	0.830
20-24	153,555	2,731	1,779	153,881	2,289	1,488	0.831
25-29	78,390	1,228	1,563	85,835	1,154	1,345	0.835
30-34	44,730	600	1,341	522,50	665	1,273	0.949
35-39	30,075	356	1,184	35,617	413	1,160	0.980
40-44	21,357	130	609	28,298	137	484	0.795
45-49	14,928	20	134	22,385	15	67	0.500
Totals	683,925	6,947	1,015.8	749,965	6,280	837.7	0.8247

"U. wom." denotes unmarried women. The "Births" are ex-nuptial only. The "Rate" is per 100,000 unmarried women of the same age-group. The "Ratio" is the "Rate" for 1921 divided by that for 1911. For the "Totals" it is also the ratio of the rates.

These rate-results are shown on Fig. 3 for the Census-year 1921, in which the broken lines show also the group-results for the Census-year 1911. The maximum-group in both cases is 20-24, and it was found by us, earlier, that the greatest probability of ex-nuptial maternity was in 1911 for women of ages 22 to 23, when it was about 0.01835, that is, 1,835 unmarried women in 100,000 would bear a child ex-nuptially, or nearly two in a hundred.* For 1921 this probability had fallen to about 0.01527, or 1,527 in 100,000—that is, about three in two hundred.

From the table above, V, and the figure illustrating it, it is seen that, for the most important ages of woman's life, the existing conditions mean that the risk of ex-nuptiality of births is the earlier risk divided by about 1.2, or multiplied by about 0.832.

*See the Table LXXIII, on p. 242 of the Math. Theory of population, which gives, *inter alia,* the probabilities of ex-nuptial births for women of all ages from 12 to 55 years of age. By making a curve of ratios for each year of age, from the final column of ratios in the above Table V, and treating the values as factors to be multiplied into the probabilities given in Table LXXIII, those for 1921 would be very accurately ascertained for each year of age. (See column xvi of the table in question.)

6. *Initial and terminal frequency of ex-nuptial births.*—Apart from its merely statistical interest, the increasing frequency of ex-nuptial births initially, and its decreasing frequency terminally, are of physiological (as well as of social) interest. For that reason the number of the occurrences (mothers) in Australia have been taken out for the sixteen years, 1910 to 1925 inclusive, the middle date being 1918.0; these annual averages are shown in Table VI, on line marked "No."

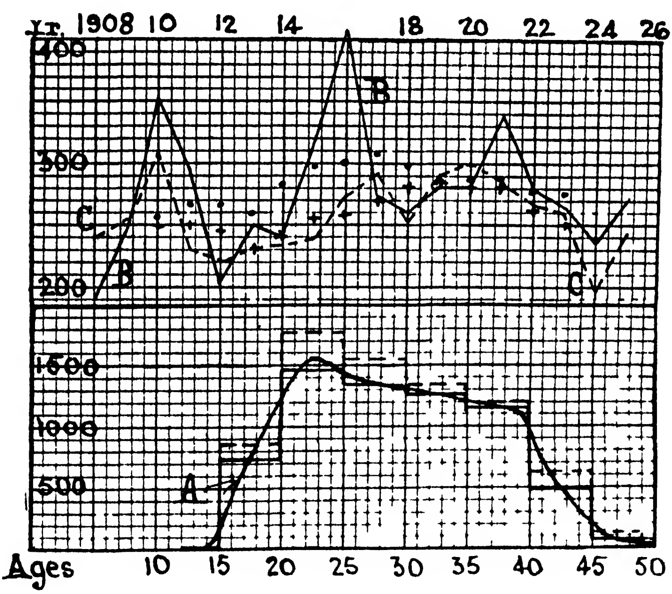

Fig. 3.

Curve A:—Numbers of ex-nuptial births per 100,000 unmarried women of the same age-group in Australia, in 1921. The rectangles in firm lines are results for 1921; in broken lines those for 1911.

Curve B:—The firm lines are the "masculinities" of first-births from 1908 to 1925; the black dots denote successive five-year means from 1910 to 1923.

Curve C:—The broken lines are similarly the "masculinities" of all-births, and the small crosses successive five-year means.

Table VI.—Average Numbers of ex-nuptial and nuptial mothers per annum, for Women of ages 12 to 17, and 37 to 53, both inclusive. Australia, 1910-1925.

Ages	12	13	14	15	16	17	..	37	38	39	40	41	42	43	44
No. E	0.5	3.2	20.3	64.4	177.7	340.4	..	74.8	74.2	58.6	47.6	27.6	28.4	20.0	11.3
No. N	0.6	0.4	4.4	23.7	155.5	550.1									

Ages	45	46	47	48	49	50	51	52	53	54	55
No. E	8.0	3.9	1.6	1.1	0.8	0.3	.06	.06	.12	0.0	0.0
No. N	360.2	161.6	74.5	35.2	12.2	8.0	1.4	0.8	0.4	0.1	0.2

It will be noticed that, although the numbers are somewhat irregular, considering that they are the means of sixteen annual results, nevertheless they show unmistakably that the mode of increase and of decrease is somewhat of the exponential type of curve. Any attempt to smooth these quantities would, however, have to proceed on somewhat arbitrary lines.

7. *Initial and terminal frequencies of ex-nuptial and nuptial-births compared.*—On the final lines of the above table are given also the average numbers, over the same sixteen years, of the mothers of nuptial-births (see the final lines marked "No. N"). For the year of age about 0.4 year later than those who were sixteen last birthday, the numbers of ex-nuptial are equal to the numbers of nuptial births; before that age they are relatively much greater, though the numbers are small. At the terminal ages of the child-bearing period, 45 to 55, the actual numbers of nuptial mothers were much greater than the ex-nuptial. The rates per married woman, and per unmarried woman, are taken out later. It will be noticed also that the records of nuptial-births end with women aged 55 last birthday, while those of ex-nuptial mothers end with women aged 53 last birthday. For the ages 12 to 17 the exact multiples of the numbers of nuptial mothers which give the numbers of the ex-nuptial, are 8, 9, 4.65, 2.71, 1.14, and 0.619 respectively; had they been, instead, 15.2, 8.36, 4.6, 2.53, 1.28, and 0.70, the curve representing

them would have been exponential (common factor 0.55). This gives an accurate idea of the relation between the two phenomena.

At the terminal end, ages 45 to 55, the factors which, similarly multiplied into the numbers of nuptial mothers, give the numbers of ex-nuptial, are as follows: 0.024, 0.024, 0.022, 0.030, 0.067, 0.104, 0.417, 0.333, 0.000, and 0.000. Thus the factors increase up to age 51; then, for age 52, the mothers of ex-nuptial births are one-third of the married mothers giving birth; afterwards there are no ex-nuptial mothers, though for ages 54 and 55 there are nuptial mothers. It will be noticed that there is no definite indication of a probable law of approach to the termination of fecundity as between the two classes of mothers.

Although the average numbers given for ages 12 to 17, and from 37 to 55, show numerically the change of frequency in the initial and closing phases of woman's procreative life from the community's point of view, they do not give any idea of the frequency in relation to the numbers of unmarried and married women at risk. Thus it is desirable to ascertain the probability of ex-nuptial, and of nuptial, maternity. These were found by dividing the numbers in Table VI by the numbers of unmarried and married women of the respective ages.* The results are given in Table VII below:

*The latter are not very accurately known. For the ages 12 to 17 they are based on the group-results of the two censuses, and a linear change between them is assumed. For 1911 the numbers for individual years were to hand. For the later ages a graduation was made from the group-results of the 1921 census. Corrections for the period between the mid-date 1918.0 and the census-date 1921.26 were made. The probabilities calculated are sufficiently exact for the mid-date.

Table VII.—Initial and terminal Probabilities of ex-nuptial and nuptial Maternity in Australia, based on cases during the period 1908 to 1925.

Ages	12	13	14	15	16	17
Probably ex-nuptial	0.1	0.7	4.3	13.8	38 6	·75.4
Probably nuptial .	6,000	2,000	2,600	2,580	4,578	5,254

Ages	37	38	39	40	41	42
Probably ex-nuptial..	85.4	87.1	70.5	59.0	35.2	37.1
Probably nuptial .	?	?	?	?	?	?

Ages	43	44	45	46	47	48
Probably ex-nuptial..	26.7	15.3	11.1	5.5	2.3	1.6
Probably nuptial ..	?	?	166.7	77.5	38.2	18.4

Ages	49	50	51	52	53	54	55	56
Probably ex-nuptial . ..	1 2	0.4	.09	.08	.17	.00	.00	.00
Probably nuptial	6.1	1.6	.80	.47	.25	.65	.14	.00

All these probabilities are expressed at per 10,000 women of the same age and status. The results for ages 12 and 13, and for ages 50 and upwards, are very uncertain because of the smallness and uncertainty of the numbers at risk.

The ratio of the probability of maternity ex-nuptially is throughout very much less than the probability nuptially, but the ratio between the two is very variable, and cannot be said to follow any simple law.

8. *Significance of human protogenesic phenomena.*—The characteristics, with the human race, of the first occurrences of nuptial-births has special interest, for the reason, among others, that, on the whole, the tendencies to impose limitations on the procreative impulse are then probably at a minimum. In Australia, too, the phenomena are presenting themselves in a community which is living under most favourable climatic conditions, and is one not subject to any serious economic pressure. Attention was called in our Math. Theory of Population to the characters of the nuptial *protogenesic surface,* or surface representing nuptial first births. This is a surface in which the z co-ordinate denotes the *relative* number of first-births occurring in any adopted unit of time (say one year), with women of age x (last birthday) and after a duration of marriage of y years (i.e., a duration lasting from, say, y to $y + 1$ years). That is, $z = f(x.y)$, z being frequency of first-

births, and x and y respectively the age of the mother and the duration of her marriage*

A little consideration will show that the general facts of protogenesis can be represented on a two-dimensional graph of the surface referred to, by means of numbered contour lines denoting equal degrees of fertility. These develop inwards from the *agenesic* region, the boundary of which shows for what ages of married women and a given duration of marriage there is absolute sterility. The summit representing the greatest possible fertility was found to be for a duration of about nine months and an age of 23 years. This surface was shown on pp. 255-6 of the Math. Theory of Population, for Australia, for the means of the period 1908 to 1914, and though it is now not quite identical therewith, it has not materially changed its characters.

8a. *Masculinity of first-births.*—From 1908 to 1925 inclusive, but with the exception of years 1908, 9, 12, 17, 19 and 20, the masculinity of the first-births was greater than that of "all" births. The simplest and most convenient way to define the preponderance of the birth of males is to make the term "masculinity" denote the difference of the numbers of males and females, divided by the sum of these numbers; algebraically, $(m - f) / (m + f)$. Multiplying these fractions, decimally expressed, by 10,000, we get the following results for the means of successive five years, such means being assigned to the middle year

*The protogenesic surface, in a perfectly rigorous mathematical theory of fertility, depends also on the ages of the husbands of the women in question. But it is so elaborate and involved as to be of little practical service. In comparisons we have therefore to assume that any two populations compared are similarly constituted as regards the associations of the husbands and wives, with respect to their ages. (See our discussion of the phenomena of di-isogeny, op. cit., pp. 350 to 368.)

of the group. These means may be regarded as the general trend.

Table VIII.—Five-year Means of the Masculinities of First-births and of all Births, for Australia, 1908 to 1925: 10,000 $(m - f) / (m + f)$.

Year	1910	1911	1912	1913	1914	1915	1916
[illegible] .	257	269	268	261	284	298	301
All births ..	251	250	246	232	240	254	258
Year	1917	1918	1919	1920	1921	1922	1928
First births ..	308	300	287	288	289	280	278
All births . ..	270	282	285	280	281	262	250

Both masculinities show fluctuations with the lapse of time, but they are not similar: the annual values are shown by curves B and C on Fig. 3. In general, the masculinity of first-births is increasing, but those of all births returned to the value it had 12 years earlier, the mean result for 1911 being the same as that for 1923, viz., 250. In themselves, these curves do not suggest any secular law of change. For individual years the highest and lowest values are: first-births, 4.10 and 1.90; all births, 3.09 and 1.98.

9. *Two classes of first-births.*—It is convenient, owing to their relatively large respective numbers, to divide first-births occurring in Australia into two classes, viz., those occurring within nine months of marriage, and those occurring later. For a considerable period the former have been about 30 per cent., and even more, of all first-births, and the lapse of time has affected this precentage but slightly.* The average interval between marriage and first-births for 1908 to 1925 inclusive was 0.462 of a year, or say 5 months 17 days. For the three six-year periods,

*So far as we are aware, no practice similar to the "bundling" of America some years ago, or of somewhat analogous practices in Continental Europe and elsewhere, exists in Australia. It may be observed here that ex-nuptial births, during 1921 to 1925, both inclusive, averaged 6,291 annually, while births occurring within nine months of marriage averaged 11,358 annually, or about 1.805 times as many.

1908-13, 1914-19, 1920-25, it was respectively 0.447, 0.464, and 0.474. The shortest average interval was 0.439 for 1909, and the longest 0.477 for 1921 and 1923. The difference is less than a fortnight, and the lengthening in the averages of the three six-year periods is only 6.2 days and 3.7 days, less than 10 days in 12 years. In the table following are shown, for all years from 1908 to 1925, the numbers of children born within nine months of marriage —193,844 in all—and the average intervals between marriage and the births. The constancy of this interval over so long a period is very remarkable.

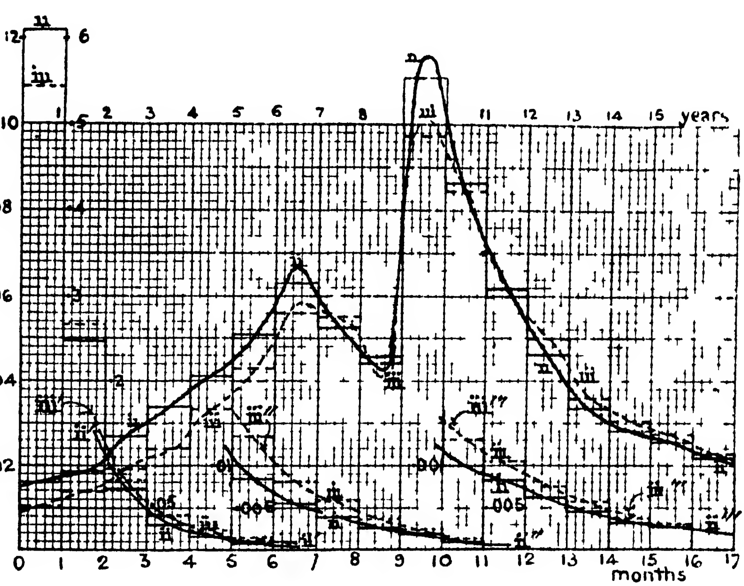

Fig. 4.

Curves of frequency of first-births for various intervals after marriage.

Curves ii, ii′, ii″, and ii‴, are for mid-date 1911.0; period 1907-14; see the firm lines.

Curves iii, iii′, iii″, and iii‴, are for mid-date 1920.5; periods 1915-25: see the broken lines.

The main curves, ii and iii, are the frequencies for intervals of successive months, from 0 to 17.

The lesser curves ii′, ii″, and ii‴, and iii′, iii″, and iii‴, are for intervals of successive years from 1 to 17.

Table IX.—Numbers of Children born within nine months of Marriage, and the average Interval of Time between Marriage and such Births.* Australia, 1908 to 1925.

Year	1908	1909	1910	1911	1912	1913	
Numbers	8,791	9,494	10,021	11,282	12,404	12,525	
Average interval .	.444	439	442	448	.452	.454	year
Year	1914	1915	1916	1917	1918	1919	
Numbers	12,245	12,000	10.420	8,564	8,344	9,102	
Average interval ..	455	456	.476	.478	.464	.461	year
Year	1920	1921	1922	1923	1924	1925	
Numbers	11,861	12,445	11,183	10.947	10 961	11,255	
Average interval .	.472	477	470	.477	475	.475	year

Later we shall show the remarkable character of the fluctuations that occur during this period of nine months.

10. *Relative number of first-births, according to all durations of marriage.*—We showed some years ago that the frequency of first-births, for different durations of marriage, presents very remarkable features. In 1917 we gave the results of the analysis of 220,021 first-births occurring during the eight years 1907 to 1914 inclusive. (See Math. Theory of Population, pp. 251-254.) In the table hereunder, the results of the analysis of 157,582 first-births occurring in the five years 1915 to 1919, inclusive, are given, coupled with the results of an analysis of 229,952 first-births occurring in the six years 1920 to 1925, inclusive. As the characteristics of the distributions in these two latter periods were very similar, the results have been combined, so that the figures in the following table furnish the results of an analysis of 387,534 first-births occurring

*The average interval was found by attributing the numbers born in any month to the middle of the month. Though not rigorously accurate the defect is quite negligible, and a more elaborate procedure does not alter the values appreciably. The average annual number is 12,115 births.

during the eleven years 1915 to 1925, inclusive.* Obviously the most valuable result of compilations of this character are the *ratios* of the first-births, during the several intervals of months and years, to the totals of the whole of the first-births occurring in the years under review. These relative numbers are shown in Table X hereunder.

Owing to the remarkable character of the early distribution of the first-births, the ratios ascertained for the eight years 1907 to 1914 are shown in comparison with those for 1915 to 1925. Both are expressed as per total of 100,000. The relative fluctuations of the numbers, for each year of age of the mothers, were given in the work mentioned (in the preceding note). It was not considered necessary to repeat this part of the analysis. (See pp. 251-257, op. cit.)

The mid-dates to which these tabulations may be referred are, respectively, 1911.0 and 1920.5, the interval being 9.5 years. One sees that during this interval significant changes have taken place in the frequency-distributions for various intervals between marriage and the first-birth afterwards. Thus for first-births occurring up to the *seventh month* inclusive after a marriage, the frequency was less for 1915-25 than it was for 1907-14; and also it was less up to the *twelfth month* inclusive, with the exception, however, of first-births during the *eighth month*.

*As the monthly distributions for the *12th* to the *23rd* month for 1915 were not available, the total was divided for monthly results in the same ratio as the results for the years 1916 to 1919, inclusive. In a similar way, in the comparative results given for the period 1907 to 1914, inclusive, the total for the second year (interval) was divided in the ratios of the results for the months of the period 1915 to 1925, inclusive. These procedures as probably sensibly exact, and are satisfactory in the absence of the monthly details. They can affect slightly the results for the months 12 to 23, and do not affect any results outside those limits. Obviously this course was to be preferred to that of omitting them.

Table X.—Relative Frequency of First-births in Australia, irrespective of the Ages of the Mothers, for various Intervals after Marriage, for the Period 1907-14, based on 220,021 First-births; and for the Period 1915-1925, based on 229,952 First-births; together with the relative totals occurring up to various Intervals after Marriage. Unit, 100,000 First-births.

(i)	(ii)	(iii)	(iv)	(v)	(vi)
During	1907-14	1915-25	*k*	Total to end of period	
1st month	1,604	1,133	0.706	1907-14	1915-25
2	1,845	1,370	0.742	1,604	1,133
3	2,693	1,943	0.722	3,449	2,503
4	3,388	2,406	0.710	6,142	4,446
5	4,116	3,334	0.810	9,530	6,852
6	5,072	4,320	0.851	13,646	10,186
7	6,304	5,633	0.894	18,718	14,506
8	5,247	5,527	1.053	25 022	20,139
9	4,574	4,441	0.971	30,269	25,666
10	11,105	9,734	0.877	34,843	30,107
11	8,657	8,474	0.979	45,948	39,841
12	6,179	6,009	0.987	54,605	48,315
13	4.630	4,977	1.075	60,784	54,324
14	3,357	3,608	1.075	65,414	59 201
15	2,838	3,051	1.075	68,771	62,909
16	2,555	2,746	1.075	71,609	65,960
17	2,166	2,328	1.075	74,164	68,706
18	1,899	2,041	1.075	76,330	71,034
19	1,682	1,808	1.075	78,229	73,075
20	1,404	1,509	1.075	79,911	74,883
21	1,294	1,390	1.074	81,315	76,392
22	1,141	1,227	1.075	82,609	77,782
23	1,006	1,082	1.076	83,750	79,009
24	796	855	1.074	84,756	80,091
2nd year	7,182	8,360	1.164	85,552	80,946
3	2,936	4,243	1.444	92,734	89,306
4	1,491	2,396	1.607	95,670	93,549
5	854	1,347	1.577	97,161	95 945
6	570	814	1.428	98,015	97,292
7	387	583	1.508	98,585	98,106
8	269	376	1.400	98,972	98,689
9	199	257	1.291	99,241	99,065
10	149	188	1.262	99,440	99,322
11	100	132	1.32	99,589	99,510
12	82	105	1.28	99 689	99,642
13	62	74	1.19	99,771	99,747
14	44	57	1.70	99,833	99,821
15	32	37	1.16	99,877	99,878
16	26.6	32	1.20	99,909	99,915
17	19.3	19.0	0.99	99,935.6	99,947
18	14 0	12.3	?	99,954.9	99,966.0
19	10.1	7.9	?	99,968.9	99,978.3
20	7.2	5.1	?	99,979.0	99,986.2
21	5.1	3.3	?	99,986.2	99,991.3
22	3.7	2.1	?	99 991.3	99,994.6
23	2.5	1.4	?	99,995.0	99,996.7
24	1.6	0.8	?	99,997.5	99,998.1
25	0.9	0.5	?	99,999.1	99,998.9
26	—	0.3	—	100,000.0	99 999.4
27	—	0.2	—		99,999.7
28	—	0.1	—		99,999.9
Totals	100,000.0	100,000.0			100,000.0

These facts are shown by the values of k in column (iv) of Table XI hereinafter, viz., by the ratios of the distribution-numbers in column (iii) to those in column (ii). The most remarkable feature of this ratio, k, is its constancy for first-births after intervals of from 13 to 24 months, it continually has the value 1.075; since a change of a single unit in the figures, where it is 1.074 or 1.076, will make it 1.075. This remarkable constancy called for special examination in order to ascertain whether great steadiness existed in the frequency of births for the monthly intervals in the second year after marriage. The apparent constancy proved to be *merely fortuitous*, as the following results for the successive months from 12 to 23 show:—

Table XI.—Variability of Frequency of First-births during the second Year after Marriage. Australia, 1916-19, 1920-22, 1923-25.

Month.	12	13	14	15	16	17	18	19	20	21	22	23
Distr.	4934	3530	3025	2791	2347	2043	1774	1424	1410	1204	1057	813
per	4836	3900	3177	2782	2269	2029	1840	1615	1379	1226	1105	875
100,000	5224	3440	2748	2648	2376	2064	1852	1558	1443	1270	1103	908
1000k′	980	1105	1050	997	966	993	1037	1134	978	1018	1045	1076
1000k′	1080	882	865	952	1047	1017	1065	962	1046	1036	998	1038

These distributions are for the four years 1916-1919, the three years 1920-1922, and the three years 1923-1925, respectively, the exact mid-dates being, therefore, 1918.0, 1921.5, and 1924.5. The values of the ratios k' have been multiplied by 1,000, and are (upper line) the distribution-values for 1921.5 divided by those for 1918.0, and (lower line) those for 1924.5 divided by the distribution-values for 1921.5. These k'-ratios no longer show the very remarkable constancy exhibited by the previous table, and one sees that there is no special steadiness in the second-year monthly intervals.

The results of columns (ii) and (iii) of the preceding tabulation have been shown on the graph, Fig. 4, the heavy curve (ii) being deduced from the monthly intervals for 1907-14, and the curve of broken lines (iii) from those for

1915-25. The second series of rectangles (ii) are for the yearly results in heavy lines, 1907-14; and for 1915-25 are (iii) shown by broken lines, the scale initially being twice as large as previously; then ten times larger again for the 5-11 year intervals; then a hundred times larger for the 10-17 year intervals. The curves show that the phenomena, though by no means identical, are characteristically similar.

What is evident from the table itself has been already referred to. The slight changes in the first twelve monthly-values of the interval are possibly referable (a) to some measure of change in social ideals; (b) to increased knowledge in contraceptive technique; (c) to other possible factors. Such observations do not appear to be applicable to the changes in the frequency for intervals greater than twelve months.

11. *Change in Age-constitution of Married Women.*—It is self-evident that, inasmuch as the fertility of the married female changes with age, populations at different dates are normally not immediately comparable, in respect of their total fecundity, unless they are identically constituted. Strictly, as we have shown elsewhere, they are not *exactly* comparable in respect of potential fecundity, unless both their frequency according to age is identical, and also that the relation of the ages of their husbands to their own ages is identical. (See "Di-isogeny in Australia", Math. Theory of Population, pp. 356-369.) In order to see whether anything was to be attributed to mere change in the age-constitution of the mothers, the constitution as indicated by the number at each age-group to the total number of ages 12 to 52 inclusive, on the occasion of the censuses of 1911 and 1921, was computed, and the results are as shown hereunder.

Table XII.—Women of Child-bearing Age, Australia, Censuses 3rd April, 1911, and 4th April, 1921.

Age-group.	Actual numbers 1881	1911	1921	[illegible] (to total) 1881	1922	1921
-15	19	19	2	6 6	3	0 2
15-19	5176	8475	8250	1803 4	1874	1016 8
20-24	41830	65372	76953	14576	10600	9485
25-29	52221	109346	145710	18197	17731	17960
30-34	49267	112593	161509	17168	18258	19907
35-39	47341	104392	145048	16496	16928	17878
40-45	41240	95293	121998	14371	15452	15037
45-49	33980	82151	99910	11840	13321	12314
50-52	15903*	39055	51940	5542	6338	6402
Totals	286977	616696	811320	100000	100000	100000
All Ages	328715	733907	999390	——	——	——

The relative numbers of married women in each age-group are very similar but are by no means identical: see the last three columns of the above table. If the distributions had been identical, then the previous results would have been directly comparable, without the application of any correcting factors. As things stand, they are only *approximately* correct for comparative purposes. For a comparison of more rigorous character one should have the product of the relative numbers into the *indexes of relative fertility*: one then (presumably) would get numbers that would represent women of equal procreative power. For a perfectly rigorous treatment, di-isogenic indices are required, viz., such as give the relative numbers of women of strictly equal procreative power, by correcting also

* In 1881, the five-year groups 45-9, 50-4, and 55-9 were respectively 33,980, 24,512, 14,114. For a unit of five years, and making the origin at the first group, the curve $y = 38{,}404 - 8{,}538x - 465x^2$ bounds the curve giving these values. The integral of this curve is $Y = 38{,}404x - 4{,}269x - 155x$. Evaluating this between the limits 1 and 1.6, we obtain the result 15,903, which is probably very nearly the correct number, and is certainly sufficiently accurate for the purpose of the computation of the relative numbers. For method see our solution given in the Math. Theory of Population, p. 67. If the 50-4 group were divided according to the numbers in 1911, the 50-2 portion would be 15,595; if according to the numbers in 1921, it would be 15,129. That is, the number for earlier years is (relatively) larger. Thus 15,903 is very probably sensibly correct.

for the age-distribution of their husbands. These, however, involve great elaboration.

12. *Relative protogenesic fertility of women of different ages.*—In actuality, the fertility of women is modified, (a) by social traditions, (b) by their prevailing mental attitude to procreative activity, (c) by the application of contraceptive measures, and (d) possibly by hygienic and other factors. Whether separated measures of (a), (b), (c), etc., as modifying factors are as yet possible or not, is not quite clear: at present the necessary statistical data do not exist.

It is important to clarify popular notions, and even official conceptions, of what constitutes an appropriate or definite measure of fertility. For example, the mere ratio of the total of ex-nuptial births to the total of all unmarried women has the defect of taking no account (in two populations), of the relative numbers of women of reproductive and of non-reproductive ages. The ratio of the total ex-nuptial births to the total of the unmarried women of *reproductive* ages, is better, but again has the defect that the relative numbers, at the different ages between the limits of that period, may sensibly vary, and thus render the two results non-comparable strictly. Again, even when the relative numbers are identical, the fertility depends to some extent upon its previous exercise, hence is affected by the previous reproductive activity of the women of each age. Two communities are not, therefore, to be regarded as necessarily quite identical potentially, even when the relative numbers of both unmarried and married women of each age are the same. An example will make the matter more clear. From the Census of 3rd April, 1911, we obtain the following data:—

Table XIII.—Total Numbers of Married Women of Various Ages, and the Number of these who had not given Birth to a Child within five Years of Marriage. Australia, Census 1911.

	Ages.	13	14	15	16	17	18	19	20	(1)
	Total numbers	1	18	92	345	1,061	2,557	4,376	7,224	(2)
(b)	Cases no births	1	13	67	183	498	1,061	1,530	2,185	(3)
(b′)	By calculation	1	14	62	197	514	1,061	1,536	2,153	(4)
	Accumd. error	0	+1	—4	+10	+26	+26	+32	0	(5)

By analysis it was found that the successive proportions of the totals,* which would give the number of cases of no births, was approximately given by the formula, $s_x =$ 0.930 (0.85^x), in which x is the age of the mother, less 13. Making the calculations we get the figures in line (4) in the above table, the accumulated errors of which are shown in line (5). The differences are not large, and this shows that the quantities, representing the diminution of the *relative number* of cases of "no births," lie on an exponential curve. This phenomenon, however, is not general, yet the later results show, notwithstanding, that the *relative number* of cases of "no births" diminish with the ages of the mothers.

Table XIV.—Total Numbers of Married Women, in Age-groups from 21 to 59, and Numbers who had not given Birth to a Child within five Years of Marriage. Australia, Census 1911.

Age groups	21-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59
Total numbers	57,896	109,138	112,525	104,619	95,890	82,237	61,447	37,900
Cases no births	13,947	15,392	7,788	4,895	2,811	1,901	969	466
Ratios..	0.2409	1404	.0692	.0420	.0295	.0231	.0158	.0123

Though continually diminishing, the diminution itself follows no simple law, but the curve is roughly analogous to an exponential curve, as its graph would immediately show. These two tables reveal the fact that, as the ages of the mothers increase, the proportions which *fail* to give birth to a child within five years of marriage, are *con-*

* In the formula, now to be given, s_x is the factor, which, multiplied into the corresponding "total number", gives the number sterile after five years.

tinually diminishing, or to state the proposition in the other way, the probability of giving birth to a child within five years of marriage, *increases* with age throughout the child-bearing period of woman's married life. In other words, *the persistence of sterility diminishes with age*, provided, of course, that the reproductive age is not exceeded. Since the ratio of sterility plus the ratio of fertility must always be unity, the finding of either will furnish what is needed as one kind of measure fertility. For the ages 13 to 20 inclusive, at maternity the sterility, up to a period of five years after marriage, was as follows:—

Table XIV. (B).

Age	13	14	15	16	17	18	19	20
Ratio obsd. ..	1.0	.72	.73	.53	.47	.415	.350	.302
Ratio calculated	.930	.790	.672	.571	.485	.412	.351	.298

The results depend, of course, on very small numbers, and are, therefore, subject to the limitation thereof; they can be regarded as representing the general law only approximately. It is to be noticed that these numbers include cases where less than five years from marriage have elapsed. The formula for the ratio of sterility of married women of age x, viz, $s_x = 0.930\ (0.85^{x-13})$, can be regarded as applicable only for the ages 13 to 20.*

13. *Percentages of first-births born within nine months of marriage.*—In Australia from 1908 to 1925 the percentages of first-births, born within nine months of marriage, were as follow:—

Table XV.—Percentages of First-births born within 9 Months of Marriage. Australia, 1908-1925.

1908-1916	33.81	34.64	35.52	36.39	35.76	34.39	33.47	33.73	30.33%
1917-1925	27.91	29.57	31.60	29.83	30.34	29.22	29.52	29.75	30.40%

* It gives the values .2534, .2154, .1831, and .1556, which applied to the totals of married women of 21 to 24 years of age, viz., 9983, 12,896, 16,331, and 18,686, gives a total of 11,915 instead of 13,947: see Math. Theory of Popn., p. 338.

These show no regular trend over all, though the first four values change very nearly linearly; they would be absolutely so were their values 33.80; 34.66; 35.52; 36.38. The 4th, 5th, 6th and 7th values are also nearly linear, but the other values are irregularly disposed, as is readily seen by graphing them. The mean of the first eight values is 34.71, and of the remaining ten values is 29.85, the mean dates being respectively for the years the centres of which were 1911.5 and 1920.5, thus the ratio in question diminished 0.43 per cent. per annum. The values for 1922 to 1925 are, however, increasing parabolically, since 29.2; 29.4; 29.8; 30.4, which are sensibly the last four values, lie on a parabola. One sees that he cannot get any indication what is likely to be the future trend of the graph of the curve, which of course necessarily is nearly identical with that of the ratio of prenuptial insemination. Leaving very premature births out of consideration, we gave reasons for believing that about 0.952 of the first-births, occurring within nine months of marriage were probably due to prenuptial insemination. See our Mathematical Theory of Population, Appendix A, of the Report of the Census of 1911, pp 276 to 279.

14. *Prenuptial insemination according to the age of mothers.*—Although the exact numbers of cases of prenuptial insemination cannot be definitely ascertained, their graph is sensibly identical in form with that of births occurring within nine months of marriage. As one might anticipate, these numbers vary greatly, according to the age of the mother at the birth; the ratios must, therefore, be taken out for such ages, in order to see the effect of age on the frequency. This, of course, could give an indication of the variation, with age, of what may be called the primary *effective* reproductive-impulse, if the number of married mothers of each age were available. The change

of percentage with age shows, not necessarily the falling-off of the urge to reproduction, but this urge as it has been modified by other factors changing with age.

We shall divide the data into three periods, viz., 1908-1911, 1912-1918, and 1919-1925, periods of four, seven and seven years respectively, the middle of these periods being the dates 1910.0; 1015.5; and 1922.5. The crude results for the percentages of the first-births occurring within nine months of marriage, for each year of age of the mother, is shown in the table hereunder, for each of the periods in question.

In order to see the law of change with age, the weighted mean has also been given, the weights assigned to the periods mentioned being 1; 2; and 2; respectively. This weighted mean has been somewhat smoothed, since the numbers for ages 12 to 16 inclusive, and from 40 to 52 inclusive, are very small, and consequently are irregular. The experience is hardly long enough to give the law in question with great precision. There are also some other irregularities. These mean-results may thus be assigned to the exact date, 1917.2.

Table XVI.—Percentages of first-births and maternities occurring within nine Months of Marriage, according to Age of Mothers. Australia, 1908-1925.

Age	1908-1911	1912-1918	1919-1925	1917.2 W Mean	Age	1908-1911	1912-1918	1919-1925	1917.2 W.Mean
12	?	?	?	99.5	25	26.47	19.06	21.10	21.5
13	100*	50*	100*	98.0	26	23.24	20.74	18.54	19.9
14	87*	89*	89*	95.5	27	20.58	18.37	16.07	18.3
					28	19.41	17.44	14.90	16.7
15	90*	85*	93*	91.9	29	18.09	16.12	13.77	15.1
16	89*	87*	87*	87.4					
17	81.4	80.6	82.3	81.2	30	16.29	14.46	12.84	14.3
18	74.3	75.1	73.7	74.4	31	16.61	14.18	11.81	18.8
19	66.5	65.7	64.3	64.6	32	15.76	14.27	12.16	13.5
					33	15.71	13.18	12.04	13.4
20	56.5	55.5	55.0	55.8	34	15.26	12.97	12.16	13.3
21	52.25	50.22	47.32	49.0					
22	41.09	38.51	36.41	38.6	35	14.64	13.43	12.33	13.2
23	35.00	32.80	29.43	31.0	36	15.59	14.55	11.64	13.1
24	29.75	27.39	24.65	25.3	37	12.94	12.06	12.41	13.0

38	12.12	12.99	11.86	12.9	45	13.4*	9.6*	18.3*	13.2
39	13.93	12.53	11.17	12.8	46	0.0*	21.3*	11.1*	13.5
					47	29.0*	12.5*	23 8*	14.4
40	13.36	11.83	13.29	12.7	48	0.0*	0.0*	10 0*	14.8
41	11.7	13.4	13.1	12.6	49	50.0*	0.0*	50.0*	15.3
42	12.9	11.8	11.3	12.7					
43	14.5	12.7	12.7	12.8	50	50.0*	0.0*	0.0*	15.8
44	14.3	9.2	16.7	13.0	51	0.0*	0.0*	0 0*	16.4
					52	0.0*	0.0*	0.0*	17.1

An inspection of the table shows that the percentage of births occurring within nine months of marriage is, on the whole, decreasing with the lapse of time. The special table hereinafter gives a definite indication of this.

15. *Change of the frequency of prenuptial insemination with the lapse of time.*—The ratios of first-births occurring within nine months of marriage, though subject to some correction in order to get absolutely correct results, doubtless affords a most accurate measure of the change, with the lapse of time, in the frequency of prenuptial insemination. The time intervals between the values are those between the middle periods previously given, and are 5.5 and 7.0 years respectively. For the ages 15 to 19, and the ages 40 to 44, it will be seen there is no sensible diminution of the percentages with the lapse of time; but for the ages 20 to 39 the percentages definitely and appreciably diminish. It will be satisfactory to take the arithmetic means for five successive age-groups, and ascertain the annual change for the two intervals. The following are the results:—

* In the above table the results marked with asterisks are very doubtful because of the smallness of the numbers. It has been carried as far as 52 years of age, because there was one birth at that age in the period over which the data extend. It has been assumed that any birth at 11 years of age, in Australia, will be within nine months of marriage, thus the percentage at 11 is taken as 100.

Table XVII.—Change with the Lapse of Time of pre-nuptial Insemination.

Group	Means of	1910.0	1915 5	1922 5	Change percentage per annum, in 5.5 years	7 years
1	15-19	80.24	78.68	80.06	— 1.56	+ 1.38
2	20-24	42.92	40.88	38.56	— 2.04	— 2.32
3	25-29	21.56	18.35	16.88	— 3.21	— 1.47
4	30-34	15.93	13.81	12.20	— 2.12	— 1.60
5	35-39	13.84	13.11	11.88	— 0.73	— 1.23
6	40-44	13.35	11.79	13.41	— 1.56	+ 1.62

We see that the negative change is becoming more rapid for group 2; less rapid for group 3; and group 4; and again more rapid for group 5. For groups 1 and 6 the changes were first negative, and then they became positive, the effect of the two being to leave the results sensibly as they were at first. If we examine the earlier table it is seen that the ages 16, 19, to 24, 26 to 36, 39 and 42, all show continuous negative changes. The other ages do not; thus for individual ages the progressions are irregular, though on the whole they move in the direction which indicates that the numbers of effective prenuptial inseminations are diminishing. This fact is, of course, compatible with any causes which diminish the *effectiveness* of insemination prior to marriage, but which are not operative to the same extent after marriage, at least until the first-birth occurs. Thus among other things it may be contributed to, by increased knowledge of contraceptive technique. That, however, may not be the only operative factor.

It is important to observe that the relative values of the changes in the percentages, furnish the most appropriate measure of the diminution or increase. Thus denoting the values for 1910.0 by 10,000, the other values are:—

Table XVIII.—Relative Changes in Ratios of pre-nuptial Inseminations.

Date	1910.0	1915.5	1922.5	Date	1910 0	1915 5	1922.5
Group 15-19	10,000	9,805	9,978	Group 30-40	10,000	8,669	7,659
Group 20-24	10,000	9,525	8,984	Group 35-39	10,000	9,473	8,584
Group 25-29	10,000	8,511	7,829	Group 40-44	10,000	8,832	10,045

The above results show, at once, that the diminution is most marked for the two groups 30-34 and 35-39. It is for these ages that the effectiveness of insemination, prior to marriage, has been most reduced by the lapse of time. This might have been anticipated. for obvious reasons. As between 1910.0 and 1922.5, the changes of the relative diminution of percentage with age were as follow, the value for 1910.0 being taken as unity:—

Table XIX.—Change in the relative Frequency of pre-nuptial Insemination, according to Age. Australia, 1910.0 to 1922.5

Age	Value	Sm	Age	Value	Sm	Age	Value	Sm.
20	.973	.97	27	.781	.78	34	.797	.79
21	.906	.93	28	.768	.77	35	.842	.81*
22	.886	.89	29	.761	.765	36	.747	.83*
23	.841	.87	30	.788	.76	37	.959	.86*
24	.828	.85	31	.711	.76	38	.9[illegible]0	.90*
25	.797	.82	32	.771	.765	39	.802	.94*
26	.798	.80	33	.766	.775	40	.995	.99*

The results in this table are somewhat irregular, thus it is doubtful whether the value 0.711, for age 31, can be taken to be more than an accidental minimum. Probably the value 0.760, for the age 30.5 to 31.5, is the minimum represented by the general trend of the results. The columns marked "Sm." give the smoothed curve, the values marked with asterisks being, however, very uncertain, since they are dependent upon small numbers.

16. *Variation of fertility with age and time.*—The numbers of first-births can be made the basis of a measure of the changes, with age and with time, in *effective fertility.* While they do not at all afford a measure of the true

relative *physiological fertility* at each age and at different epochs, since the fertility is modified by various factors which probably vary in a complex manner with both age and time, they do give a valuable basis for the study of changes, with the lapse of time, of the *effective fertility*. The data do not yet exist for an accurate measure of the physiological possibilities of fertility at different ages, and of the possibilities of ascertaining whether or not this varies with time. In order to eliminate absolute changes in the effective fertility, so as to compare, for different ages, its changes with time, we can consider how a given number of births, say 10,000, occurring annually, are distributed according to age; that is, how many are contributed by women of different ages, from say 12 to 52 years of age. We shall make this comparison both for (a) *first-births occurring within nine months of marriage,* and (b) for *all first-births.* For the former, we take the totals of all births of this character occurring in the years 1908 to 1911 inclusive, and show the relative number for each age of the mothers. For the latter we take all the first-births occurring in the years 1913 to 1918, inclusive, and all those occurring in the years 1919 to 1925, inclusive. As the distributions appeared to be sensibly identical for these, their sums were taken, and the distribution was made for 10,000 according to age. Thus the two results so obtained are referable to the exact dates 1910.0 and 1919.0. These are given in columns (ii) and (iii) in the following Table XX. For the total first-births it was deemed desirable to get the three distributions, viz., for the three successions of years, the centres of the periods being 1910.0, 1915.5 and 1922.5. These are given in columns iv., v. and vi. of the Table.

Table XX.—Relative Distribution of First-births according to age. Australia, 1908–1925.

i. Age	ii. 1910.0	iii. 1919.0	iv. 1910.0	v. 1915.5	vi. 1922.5	vii. 1917.2	viii. 1917.2
	Births up to 9 months		All First-births			To 9 m.	All.
12	0.0	0.0	0	0	1	0.0	0.04
13	0.3	0.2	1	2	1	0.22	0.12
14	2.8	3.5	11	10	14	3.36	1.18
15	16	18	62	67	65	17.75	6.52
16	108	120	427	425	432	118	42.80
17	336	385	1450	1435	1506	375	146.9
18	726	779	3434	3205	3321	769	330
19	1075	1076	5682	5102	5229	1077	527
20	1109	1113	6908	6238	6333	1113	641
21	1281	1248	8623	8193	7775	1256	811
22	1099	1060	9401	9094	8585	1069	895
23	930	900	9338	9363	8706	907	910
24	727	707	8590	8750	8235	712	851
25	590	557	7836	7849	7809	564	783
26	452	449	6844	7212	7070	450	708
27	347	339	5923	6124	6154	341	610
28	280	277	5066	5296	5401	278	529
29	204	210	3970	4225	4617	209	433
30	162	166	3501	3726	3879	165	375
31	118	117	2501	2713	2951	117	276
32	99	104	2202	2369	2582	103	242
33	80	76	1780	1813	1939	77	186
34	61	65	1405	1499	1720	64	157
35	49	54	1173	1256	1395	53	129
36	40	44	979	1023	1113	43	105
37	28	32	762	793	835	31	80
38	23	28	661	670	730	27	69
39	20	19	498	517	507	19	50.9
40	14	15.3	365	373	387	15	37.7
41	7.2	10.4	205	230	260	10	23.7
42	6.0	7.0	172	178	198	6.8	18.50
43	4.2	4.7	102	107	125	4.5	11.38
44	2.2	2.8	62	71	65	2.6	6.70
45	1.5	1.5	40	35	32	1.4	3.50
46	0.8	0.9	13	19	14	0.8	1.59
47	0.4	0.4	6	10	8	0.36	0.84
48	0.3	0.2	2	4	4	0.22	0.36
49	0.2	0.1	2	2	1	0.14	0.16
50	0.1	0.0	2	1	0	0.07	0.08
51	0.0	0.0	1	0	0	0.03	0.04
52	0.0	0.0	0	1	1	0.00	0.02
	10000	10000	100000	100000	100000	10000	10000

Table XXI.—Age-distribution-ratios of Cases of First-births occurring within nine Months of Marriage, as related to all First-births. 1917.2.

i.	ii.	iii	i.	ii.	iii	i.	ii.	iii
Age	Ratios		Age	Ratios		Age	Ratios	
12	?	2.94	25	0.72	0.724	40	0.40	0.385
13	2.0	2.94	26	0.63	0.630	41	0.42	0.380
14	2.9	2.90	27	0.56	0.558	42	0.37	0.375
			28	0.53	0.502	43	0.40	0.380
15	2.72	2.82	29	0.48	0.462	44	0.39	0.395
16	2.77	2.70						
17	2.55	2.56	30	0.44	0.438	45	0.40	0.420
18	2.33	2.33	31	0.42	0.430	46	0.50	0.455
19	2.04	2.03	32	0.43	0.425	47	0.43	0.500
			33	0.41	0.420	48	0.61	0.555
20	2.06	1.75	34	0 41	0.415	49	0.81	0.620
21	1.55	1.47						
22	1.19	1.20	35	0.41	0.410	50	0.88	0.695
23	1.00	1.00	36	0.41	0.405	51	0.75	0.775
24	0.84	0.848	37	0.39	0.400	52	0.00	?
			38	0.40	0.395			
			39	0.37	0.390			

The large differences between the crude and the smoothed values (iii.), for the beginning and the end of the table, are of very little consequence, because the numbers affected are very small. It will require more than 18 years' results to ascertain the law for these ranges with precision.*

The smoothed numbers in the preceding table can be used in the following way:—The total number of first-births being to hand, the numbers borne by mothers of each age, can be found approximately by distributing them according to column (viii.) of the penultimate table, when the numbers born, before nine months after marriage, will

* The preceding results depend upon an aggregate female population of about 2,457,321 for the date 1917.2 (found by assuming that the change between the Census of 3rd April, 1911, and 4th April, 1921, was linear). The total numbers of females of the reproductive ages 12 to 52 (found in the same way) was 1,514,633, that is 0.616376 of the total. Of these the number of married women, between the ages 12 to 52 inclusive, was about 891,604, or about 0.588663 of the total females of these reproductive ages. These numbers and ratios all refer to the exact date 1917.2.

be approximately given by multiplying these results by the corresponding age-distribution-ratios in the last table. Or alternately, if the total number of those born before nine months have elapsed from marriage, the numbers contributed by mothers of each age can be approximately found by distributing them according to column (vii.) of the penultimate table.

18. *Age and measurement of the maximum intensity of the gonad urge.*—In Table XX., section 16, column (vii.), it was shown that first-births within nine months of marriage were relatively most frequent for age 21, or more precisely at exact age 21.43. For all first-births—see column (viii.)—it was later, viz., age 23, or more precisely at age 23.21. The table given hereinafter, XXIII., shows that for ex-nuptial cases it is at age 21, or, smoothing the curve of probabilities somewhat, it is found to be more precisely at exact age 21.21. Thus in general the effective gonad urge appears to be most intense at the exact age 21.3 nuptially.

In 1917 we found that for the year 1911, the nuptial probability was greatest for the exact age 18.73; its amount was 0.4849, see Math. Theory of Popn., p. 243. In the table hereunder for ex-nuptial births, its amount in 1921 will be found to be 0.01534 (only about one thirty-first part of the nuptial probability ten years earlier, viz., in 1911). At that date, however, 1911, the ratio of the two was as 1 to 26.5. We estimate that, very approximately, the nuptial probability of maternity for 1921 was 0.4307, which divided by 0.01534 gives 28.08, i.e., *the ex-nuptial probability is only about one-twenty-eighth of the nuptial,* when it is at its maximum. For all ex-nuptial births, for women of all reproductive ages, the relation to all nuptial births was found to be as follows:—

Table XXII.—Relative Frequency of nuptial and ex-nuptial Births.

Years	1919	1920	1921	1922	1923	1919-23
Ex-nuptial births = nuptial births divided by	17.88	19.66	20.05	21.26	20.55	20.867

This indicates that over all ages combined, the difference in frequency is slightly less than at the age of maximum frequency. It may be remarked that for 1921 the exact age of maximum frequency, of births occurring within nine months of marriage, was about 21.4; and women of 21 years of age gave birth to 1574 children out of a total of 12,445 for women of all ages giving birth within nine months: that is, the total was 7.906 times as many This tends to confirm the age of the maximum intensity previously found, but throws no light upon the measure of its intensity.

The matter can be envisaged thus:—The effective gonad urge is greatest at about exact age 21.3: this is shown by the fact that both nuptial cases occurring within nine months of marriage and ex-nuptial cases gave a maximum rate per woman for this age (actually 21.4 and 21.2). At its maximum it is ex-nuptially only about one-twenty-eighth, or more exactly only 3.561 per cent. as effective as in nuptial cases at the maximum. For women of all ages, however, it is 4.79 per cent. as effective. These changes should be measured on the occasion of each Census, when the necessary material can be made readily available.

19. *The probability of ex-nuptial maternity.*—On p. 242 of "The Math. Theory of Population," a table was given of the probability of ex-nuptial maternity, based upon ex-nuptial births, and the numbers of women who had "never married." In the table hereunder, XXIII., the "never married," "the widowed," and the "divorced," are all included as forming the most suitable divisor, for

ascertaining the probability. The fractions found by dividing the ex-nuptial births by their number are multiplied by 100,000; so that they represent the number of cases of ex-nuptiality at each age, per 100,000 of the same age, last birthday.

Table XXIII.—Number of ex-nuptial Cases of Maternity per 100,000 of Women of the same Age, who are unmarried, or widowed or divorced. Australia, 1921.

Age	No.	Age	No.	Age	No	Age	No
11	0.0	21	1527	32	1197	42	397
12	1.1	22	1467	33	1163	43	299
13	9.1	23	1483	34	1138	44	152
14	43.6	24	1397				
				35	1141	45	105
15	117	25	1345	36	973	46	54
16	361	26	1342	37	893	47	11.5
17	712	27	1203	38	907	48	20.3
18	1154	28	1308	39	772	49	2.9
19	1452	29	1186				
				40	602	50	5.8
20	1515	30	1338	41	313	51	0.0
		31	1025			52	2.9
						53	0.0

These are the "crude" results, and for practical use they need to be "smoothed." For smoothing purposes the values should be made to decrease from 1527, for ag 21, to 0.0 for age 53, or perhaps for age 54.*

The above table represents the mean results of five years' birth-cases for each age, the census year, 1921, being the middle year. The inconsistencies are doubtless very largely due to mis-statements of the ages by the mothers. To a lesser extent they may also be affected by the fact that the populations for each year of age had to be obtained from the group-results.

In general, it may be noted that the numbers of cases of maternities are considered, not the number of children born, unless expressly indicated.

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* Smoothed values from age 21 onwards may be taken as:—1527, 1500, 1452, 1397, 1352, 1310, 1284, 1266, 1246, 1226, 1206, 1188, 1166, 1138, 1100, 1012, 928, 830, 706, 602, 432, 304, 230, 168, 122, 64, 30, 14, 7, 4, 2, 1.

20. *Numbers of mothers as related to the numbers of children.*—The numbers of mothers, owing to multiple births, are, of course, slightly less than the numbers of children. The excess over one child per birth we have shown to be, for Australia 1907 to 1914, as follows:—

For Nuptial Cases—

$B = 1 + 0.00064\ (x - 12)$,....for ages up to 38 inclusive,
$B = 1.01664 - 0.00129\ (x - 38)$,....for ages 39 to 51 inclusive.

For Ex-nuptial Cases—

$B = 1 + 0.00070\ (x - 12)$,....for ages up to 38 inclusive,
$B = 1.01820 - 0.00140\ (x - 38)$,....for ages 39 to 51 inclusive.

(See Journ. Roy. Soc.: N.S.W., vol. lix., pp. 138-9; also Math. Theory of Population, 1917, pp. 308-310). These corrections, however, are not large compared with the uncertainties of the numbers deduced by such formulae as we are considering.

21. *Points for further study.*—From Table V., section 5, it was seen that the rate at which children are born ex-nuptially, initially increases with age, reaching a maximum for age 21; see Table XXIII., section 19. It then diminishes slowly till age 35 is reached; see the same table; and then diminishes rapidly to the end of the reproductive period of woman's life. This would seem to suggest that the gonad urge, as modified by all operating factors, must fall off in a somewhat similar way. From Tables XIII., XIV., and XIV. B., of section 11, however, it is seen that the ratio of the number of cases of "no births" within five years of marriage, to the total numbers of married women, diminishes with age at least from about age 21 to the end of the procreative period. Again, Table XVI. of section 14 shows that the percentages of first-births born within nine months of marriage, decrease steadily to age 41 of the mother, after which they increase slightly till age 52. The

correlation of these facts calls for further study. They may throw light upon the way in which the response to the procreative impulse is modified, and make more clear the facts about the age of its normal greatest intensity.

22.—*Conclusions.*—Though in the world generally, Australia is among the countries with a small percentage of ex-nuptial births, it appears likely that this percentage will decrease still further. Although it fluctuates in a peculiar manner, it has been falling from the beginning of this century. It may, however, be an oscillating phenomenon.

Since 1916 the percentages of nuptial first-births, occurring within nine months of marriage, has been fairly constant. The large and very remarkable distribution of the frequency of the births during this first nine months, which characterised the period 1908 to 1914, still continues. It commences with an appreciable frequency, rises rapidly until the middle of the sixth month; falls quickly to the middle of the eighth month; then rises very rapidly till the middle of the ninth month; after which it falls rapidly to the beginning of the fourteenth month. After this it falls with increasing slowness up to an interval of twenty-eight years from marriage. These features are characteristic also for the period 1915 to 1925. The frequency, however, has sensibly lessened for the first seven and a half months; is less during the ninth and tenth month; and from the beginning of the twelfth month, the frequency of births is greater than it was for the earlier period, a state which continues up to an interval of sixteen years after marriage.

The frequency of ex-nuptiality, according to the age of the mother, has not characteristically altered; its amount, however, is sensibly less for 1921 than it was for 1911. It rises rapidly from age 12; it reaches a maximum at age 21,

last birthday; it then diminishes slowly till age 35 is reached; when it diminishes much more rapidly until age 53 is reached. This last is the age when it ceases.

The mode of variation of births occurring within nine months of marriage, when age is taken into account, and of ex-nuptial births, indicates that, either for mere statistical purposes, or for more important social biological inquiries, they should continue to be independently recorded; and the records are worthy of independent analysis. They will later reveal important elements in the social and ethical evolution of the Australian people.

The evidence of variations of fertility, and of sterility measured in different ways, have not so far been appropriately correlated, and the subject calls for further study. Measures of fertility according to age are not direct measures of the intensity of the gonad urge; they measure only its action as modified by social customs and traditions, by advances in a knowledge of contraceptive technique, and by other possible factors. Statistical data, on a sufficiently wide basis, do not yet exist for the determination of the part played by the several modifying factors.

OBSERVATIONS ON RODENTS AND THEIR PARASITES.

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From time to time in different parts of the world, investigations have been carried out with a view to obtaining information as to the occurrence of Ecto and Endoparasites of rats, in some cases records have been put forward showing the frequency and seasonal prevalence of pregnancy, and the number of foetuses present in such pregnancies. Shipley (1908) compiled a list of the then known parasites occurring on or in rats; these parasites had previously been collected by various authorities, since that time additions have been made to the number. Stiles and Hassell (1910) published a check list of parasites. Hall (1916) contributed a paper containing a list of parasites from the *Rodentia* and other orders. Johnston (1916) in his paper on Endoparasites recorded in Queensland, gives a list of parasites from the *Rodentia*, and (1918) published a paper on the Entozoa of rats and mice. Moll (1917) gives a short list of parasites found by him in rats at Madison, Wisconsin, U.S.A.

Cleland (1918) in his Presidential Address to the Royal Society of N.S.W. deals with rats from a general and parasitological point of view. Balfour (1922) contributes a paper dealing with the parasites of wild rats in England.

Foulerton (1919) deals with the protozoal parasites of rats in London, while various papers have appeared on the individual parasites of rats.

The ectoparasites of rats and mice have been variously dealt with, notably by Bacot (1919), Hirst (1914), Newstead & Evans (1921), Nuttall & Strickland (1913), and Strickland & Merriman (1913), etc.

Since the occurrence of the Plague epidemic of 1921-22 in Australia, the Health Authorities, both Commonwealth and State, decided that a systematic examination of all rats and mice for the presence of *Bacillus pestis* should be a routine procedure in the Health Laboratories. Townsville being situated in the tropics, and being one of the centres for such examinations, it was considered a good opportunity for carrying out a survey of ecto and endoparasites of the material dealt with, also taking cognisance of proportion of males to females and the frequency of pregnancies occurring throughout the year. Arrangements were made with the City rat-catcher for a supply of living rats, on which portion of the present investigation was carried out, and although the number of living specimens received was not large, it is felt that it will give a fair estimate of the parasites to be found; the other portion of the work was carried out with all rats received dead or alive. During the course of this investigation, which extended over a period of thirteen months, i.e., from the beginning of September, 1925, to the end of September, 1926, a total of 1779 rats and mice was dealt with; of this number 222 were living specimens, and were killed by means of chloroform just prior to the examination.

The following points were investigated:—

1. Ectoparasites.
2. Plague routine.
3. Leprosy.
4. Protozoa.

5. Metozoa.
6. Pathological conditions.
7. Pregnancies.

Ectoparasites.

The ectoparasites recorded during the course of this investigation were all fleas, although shortly after the termination two rats were received at the laboratory which were literally covered with an undetermined genus and species of mite.

The rodents were received at the laboratory and were placed in a closed jar and sprinkled with naphthalene; by this method the fleas usually left the rats and could be easily collected from the jar; after this treatment so as to ensure having collected the whole of the fleas, the rat was then introduced into a closed jar containing a chloroform pad; when dead the rat was taken out and placed on clean white paper and a fine tooth comb used. In all a total of 222 rats was treated as above, while all dead rats were combed immediately on receipt, but fleas were found only in isolated cases on the dead material.

A total of 536 fleas only being recorded which was equal to 2.4 fleas per rat, taking only the living specimens into consideration; of these 493 were *Xenopsylla cheopis* Roths, 33 *Ctenocephalus felis* Bouche, 8 *Ctenocephalus canis* Curtis, 1 *Pulex irritans* L, and 1 *Ctenopsylla musculi* Kol. Table 1 shows the monthly total of rats and the number of fleas collected.

Plague.

During the period under review, a total of 1779 rats and mice was examined for the presence of *Bacillus pestis*; all proved to be negative.

Leprosy.

The disease now known as rat leprosy was first discovered by Stefansky (1903); it has since been recorded in various

parts of the world. In Australia it has been noted by Tidswell (1904), Bull (1907), and Priestley (1913). In Hawaii Brinckerhoff (1910) examined 16,000 rats without finding a single infection; this also applies to nearly 400 rats examined by Bayon (1913) in South Africa. Cleland (1918) points out that an examination of about 560,000 rats in N.S.W. showed only five infected; on the other hand, Priestley in North Queensland found twelve rats infected out of a total of 220 examined; six of these had the lymphatic form, and six the musculocutaneous form. His figures showed that the disease was apparently much more prevalent in North Queensland than in New South Wales. Priestley's investigation gave one rat infected in every 18.3 examined, while Cleland's showed that one rat in every 100,000 was infected. In the present investigation extending over a period of thirteen months, a total of 1779 rats was examined, the examination in each case consisting of a microscopical examination of either the axillary or inguinal glands and both in a large percentage of cases. The species examined were fairly equal as far as the three common rats were concerned, but very few mice were dealt with, and a few water rats *Hydromys chrysogaster*.

During this period four rats were found to be infected, and all were *Epimys norvegicus* females, three of which had the musculocutaneous type and one the lymphatic type. These infections were confined to the first four months of the investigation; confining the infection rate to these months gives us one rat infected to every 92.5 examined, but taking it over the whole period would be equal to one infected rat to every 445 examined. This rate is decidedly higher than the N.S.W. rate, but is distinctly lower than Priestley's findings in the same locality.

Since the foregoing observations were concluded a matter of seven months have elapsed, and a further 655 rats have

been examined for this disease, 258 being *E. rattus alexandrinus,* 67 *E. rattus* and 330 *E. norvegicus;* of this number seven rats all *E. norvegicus* were found to be infected with leprosy, three having the musculocutaneous type and four the lymphatic type. The batch containing these infected rats was received from the same warehouse on the same day. Attention is drawn to the fact that all the infected rats were received from the following places, two from the jetty wharf, one from an hotel, one from a butcher's shop and seven from a grocery store.

Trypanosoma lewisi (Kent).

This parasite was first recorded from *Epimys norvegicus* and *Mus rufiscens* by Lewis (1878). In Australia Bancroft (1888) appears to have been the first to record this trypanosome from rats in the Brisbane district. Cleland, Johnston and Pound recorded the occurrence individually from Perth, Sydney and Brisbane. Balfour (1922) found in England that 38.2% of *Epimys rattus* and 19% *Epimys norvegicus* were infected. Breinl (1913) gives the percentage in North Queensland as 15%.

In this instance the percentage of 14.0% was recorded, i.e., 31 rats infected out of 222 living rats examined, of this number 9 were *Epimys rattus,* 10 *Epimys rattus alexandrinus* and 12 *Epimys norvegicus.* It was decided also to make an examination of the dead rats for the presence of the parasites, these had been dead for varying periods when examined of from 1 to 18 hours; this showed a total of 50 infected out of 1557 examined, equal to 3.2%, of which 16 were *Epimys rattus,* 16 *Epimys rattus alexandrinus* and 18 *Epimys norvegicus.* Three mice *Mus musculus* and five water rats *Hydromys chrysogaster* were found to be negative.

Legtospira icterohaemorrhagica.

It was considered to be of interest to carry out a survey of rats in the tropics for this parasite, in all a total of 222 rats was examined. The rats were received at the laboratory in a living condition, a large portion of them was placed in a urine collecting apparatus for the urine collection, which was then centrifugalized and examined by the dark ground method, in a further portion wherever possible the urine was obtained direct from the bladder and examined in the same way, all with negative results. The continuation of the examination consisted of grinding the kidneys and making dark ground preparations and examinations of a proportion of the rats; and making two smears of the kidneys of each rat, these were stained with Giemsa and examined. Result negative in each case.

Spirochaetosis.

The blood of all living rats was specifically examined for the presence of spirochaetes. Results negative.

Coccidia.

Eimeria sp.

Eimer (1870) described the process of schizogony of *Eimeria falciformis* in the mouse and records a similar parasite in rats. Grassi (1881) noted coccidia in rats. Wassilewski (1904) reports that Nissle had found Eimeria in a black rat in Berlin. Ohira (1912) in Japan reports the finding of a new coccidia in a rat, naming it *E. miyairii.* Reich (1912) gives a full account of *E. falciformis* in the mouse and considers it identical to that found by Grassi. Rudovsky (1921) found coccidia in young rats and came to the conclusion that it was identical with that of the mouse; he also reports the finding of *E. stiedae* in four rats. Balfour (1922) records the finding of *E. falciformis* in 21% *Epimys norvegicus* and in 50% *Epimys rattus.* Dieben (1924) assumes that the rat coccidia are specific;

he failed to transmit it to mice, guinea pigs and rabbits, but succeeded with *E. rattus* and *E. norvegicus;* he names the parasite *Eimeria nieschulzi.* He failed to infect rats with *E. stiedae.* Azim (1927) found coccidia in white and wild rats in London, but in view of the confusion as to whether the parasite is *E. miyairii* Ohira or *E. nieschulzi* Dieben, he has left the question of species open. In the present investigation coccidia was absent in 36 *Epimys rattus,* and present in 2, or 4.26% of 47 *Epimys rattus alexandrinus,* and in 21, or 15.2% of 138 *Epimys norvegicus.* The parasite was present in the intestine, more especially in the caecum, and was in large numbers. Two specimens of the water rat *Hydromys chrysogaster* were found to be negative. Owing to the fact that neither Ohira's nor Dieben's paper has been consulted, the question of species is being left open, and attention is drawn to the fact that the asexual forms have not been found in sections of the epithelium of the gut. Investigations are proceeding into the question of infection with other animals, the results of which will be reported on at a later date.

Eimer (1870) "Ueber die ei-und kugelförmigen sogenannten Psorospermien der Wirbelthiere" Wurzburg. Grassi (1881) Att. Soc. Ital. Sci. Nat. xxiv. p. 135. Wassilewski (1904) "Studien und Microphotogramme zur Kenntnis du pathogenen Protozoen, L Untersuchungen über den Bau, die Entwichlung und über der pathogene Bedeutung der Coccidien". Leipzig.

Ohira (1912) (*Eimeria myairii*) Mitt de med Geselsch., Tokio, xxvi. p. 17 (das Referat Fukuharas enthalten in Centr. f. Bakt. Abt. 1. Ref. LVIII. p. 308). Reich (1913) Arch. f. Protest xxviii. p. 1. Dieben (1924) Proeschr Veeartsenijk Hoogesch. Utrecht. Azim (1927) Proc. Roy. Soc. of Med. xx. 5, pp. 701-4.

Helminths.

Johnston (1918) found helminths "in the gastro-intestinal tract" in 23.5% of *Epimys rattus;* 21% *E. rattus alexandrinus* and in 42.1% of *E. norvegicus.*

Moll (1918) found 88% of the rats he examined were infected with round worms, and 20% with *Hymenolepis diminuta,* while 4% contained *Trichinella spiralis* Owen.

Balfour (1922) found helminths in 32.4% *E. rattus* and 28.4% *E. norvegicus,* while in the latter species he found 48.3% infected with the bladder worm *Trichosomoides crassicauda* Bell. For this parasite in Australia Johnston (1918) records a finding of 0.6% in *E. rattus;* 0.4% in *E. rattus alexandrinus* and 31.2% in *E. norvegicus.* In the present investigation no bladder worms were recovered, but a fair number of eggs were seen which were thought to belong to this species.

Nicoll and the writer (1913 onward) collected this worm from *Epimys norvegicus* on seven occasions, which was recorded by Nicoll; during the same period he recorded *Spiroptera obtusa* from *Epimys norvegicus* and *Hydromys chrysogaster* and from the latter an unidentified cestode from the intestinal wall which was encysted.

The records of the findings in Townsville rats are shown in a monthly record of rats examined, the number parasitized by the various parasites, the aggregate number, and percentage incidence, in Table I.

Hormorhynchus moniliformis Br.

Synonym—*Gigantorhynchus moniliformis.*

Johnston (1918) in his survey of rats for endoparasites, found this parasite present in 5% of *Epimys rattus;* in 2% *Epimys rattus alexandrinus* and 1.65% *Epimys norvegicus.* In the present instance the rats examined showed percentages as follows:—28, or 20.3% of *Epimys*

TABLE I.

INFECTION.	1925. Sept. Rats Examined	Positive	Oct. Examined	Positive	Nov. Examined	Positive	Dec. Examined	Positive	1926. Jan. Examined	Positive	Feb. Examined	Positive	Mar. Examined	Positive	April Examined	Positive	May Examined	Positive	June Examined	Positive	July Examined	Positive	Aug. Examined	Positive	Sept. Examined	Positive	TOTAL Examined	Positive	% % POSITIVE
Coccidia sp.	12	3	30	2	16	5	25	5	17	1	20	0	10	1	8	1	8	0	29	0	22	0	14	3	11	2	222	23	10.4%
Trypanosoma lewisi-Living rats	12	2	30	4	16	6	25	7	17	4	20	0	10	0	8	0	8	0	29	2	22	0	14	2	11	4	222	31	14.0%
Dead rats	108	7	55	1	44	0	80	0	54	0	78	0	139	3	379	13	102	1	179	7	151	8	65	3	119	7	1557	50	3.2%
Leprosy	120	1	85	1	60	1	105	1	71	0	98	0	149	0	387	0	110	0	208	0	173	0	79	0	130	0	1779	4	0 22%
Hormorhynchus moniliformis	12	4	30	5	16	7	25	7	17	1	20	5	10	0	8	1	8	0	29	2	22	0	14	1	11	4	222	37	16.4%
Hepaticola hepatica . ..	120	9	85	8	60	4	105	11	71	3	98	6	149	4	387	3	110	9	208	28	173	15	79	3	130	1	1779	114	6 41%
Gangule terakis spumoso .	12	1	30	2	16	2	25	3	17	0	20	1	10	0	8	0	8	0	29	3	22	1	14	1	11	0	222	14	6 3%
Syphacia obvelata	12	0	30	1	16	0	25	0	17	0	20	0	10	0	8	0	8	0	29	0	22	0	14	1	11	0	222	2	0.9%
Gongylonema sp.	12	2	30	0	16	0	25	0	17	0	20	0	10	0	8	0	8	0	29	1	21	1	14	2	11	2	222	8	3.6%
Trichuris-muris	12	2	30	0	16	0	25	3	17	0	20	2	10	0	8	0	8	0	29	6	22	5	14	4	11	3	222	25	11.3%
Hymenolepis diminuta... ..	12	3	30	4	16	5	25	3	17	0	20	8	10	0	8	0	8	0	29	5	22	2	14	0	11	4	222	34	15.3%
Hymenolepis nana	12	0	30	0	16	0	25	0	17	0	20	1	10	0	8	0	8	0	29	2	22	0	14	1	11	1	222	5	2.45%
Cysticercus fasciolaris	120	4	85	6	60	0	105	1	71	0	98	1	149	3	387	1	110	1	208	1	173	0	79	0	130	0	1779	18	1.0%
Xenopsylla cheopis	...	92	...	108	.	46	..	91	..	9	..	12	...	1	...	0	..	0	..	56	..	19	..	35	..	24	...	493	...
Ctenocephalus felis	..	1	..	5	.	0	..	15	..	1	...	1	...	0	..	0	..	0	..	0	..	1	..	1		8		33	...
Ctencephalus canis	...	0	.	5	..	0	..	[illegible]	...	0	.	0	..	0	..	0	...	0	...	2	.	1		0	..	0	...	8	...
Ctenopsylla musculi	..	1	.	0	.	0	..	0	...	0	..	0	...	0	..	0	..	0	...	0	...	0	..	0	..	0	...	1	...
Pulex irritans .		0		0	.	0	.	0	..	1		0	.	0	.	0	..	0	.	0		0		0		0	..	1	...

norvegicus, 9, or 19.1% of 47 *Epimys rattus alexandrinus*, 36 *Epimys rattus* proved to be entirely negative; although this species had been found to harbour this parasite previously in the same locality (Nicoll). The greatest number obtained from one rat was 160 individuals; the size was variable, corresponding roughly to Johnston's findings. But as will be noted above, the percentage of infection is very much higher for *norvegicus* and *alexandrinus*.

Hepaticola hepatica (Bancroft).

Synonyms—*Trichocephalus hepaticus* Banc. *Capillaria hepatica* R. *Trichosoma hepaticum*.

In Australia this parasite appears to have a fairly wide distribution. Bancroft (1893) states that nearly all rats examined by him were infected, but he does not give the species examined. Johnston (1918) records the fact that rats examined in Sydney during 1909-10 showed the following infection rate: *Epimys rattus* 3.4%, *Epimys rattus alexandrinus* 2%, *Mus musculus* 2.74%. He states that *Epimys norvegicus* is probably more highly infected owing to its cannibalistic habits. Balfour (1922) found this parasite only on one occasion, but he does not give the species of rat.

In the present series the infection rates were as follows: *Mus musculus* nil, only 3 examined; *Epimys norvegicus* 52, or 8.5% of 614 examined; *Epimys rattus* 24, or 5.2% of 461 examined; *Epimys rattus alexandrinus* 38, or 5.5% of 696 examined; and *Hydromys chrysogaster* nil, 5 examined. Of the total examinations of 1779, the number infected was 114, or 6.4%.

I have to record a similar finding to Johnston's, viz., the finding of the parasite in the spleen. This occurred in 2 *E. norvegicus* and 1 *E. rattus;* in these cases both the livers and spleens were very heavily parasitized. Work

on the life history has been carried out, notably by Railliett (1889), Bancroft (1893), Galli-Valerio (1905), Hall (1916) and Johnston (1909-10); the latter author supplies a very exhaustive account of the work done with this parasite.

Trichuris muris Schr.

Synonym—*Trichocephalus nodosus* Rud.

Johnston's findings for this parasite showed the following percentages: *E. norvegicus* nil, *E. rattus* 2.5%, *E. rattus alexandrinus* 1% and *Mus musculus* 16.4%. The following infection rates were recorded in the present series: *E. norvegicus* 21, or 15.2% of 138 examined, *E. rattus alexandrinus* 3, or 6.4% of 47 examined; *Hydromys chrysogaster* one examined, one infected; *E. rattus* nil, 36 examined. No mice were examined.

Ganguleterakis spumosa (Schr.).

Synonyms—*Heterakis spumosa* Schr. *Ganguleterakis gangula* Lane.

The finding of this parasite in Sydney rats recorded by Johnston (1918) occurred in 0.84% *E. rattus;* 1% *E. rattus alexandrinus*; 24.8% *E. norvegicus* and 1.4% *Mus musculus.* The findings in North Queensland were as follows: *E. norvegicus* 13, or 9.4% of 138 examined; *Hydromys chrysogaster,* of one examined, one infected; *E. rattus* and *E. rattus alexandrinus* both negative, the number examined being 36 and 47 respectively. No mice were examined.

Syphacia obvelata (Rud.).

Synonyms—*Ascaris obvelata* Rud. *Oxyuris stroma* Linstow.

Balfour (1922) found a 3% infection in *E. rattus.*

Johnston's percentages of Sydney rats were *E. rattus* 10%, *E. rattus alexandrinus* 2%, *E. norvegicus* 1.6% and

Mus musculus 26%. The present investigation showed 0.9%, or only two infections in 222 rats examined, both occurring in *E. rattus alexandrinus.*

Gongylonema sp.

Worms belonging to this genus were found on eight occasions in the intestines of the rats; viz., four times in *E. norvegicus* and twice in *E. rattus alexandrinus;* once in a white mouse and once in *Hydromys chrysogaster;* the numbers examined being 138, 47, 1 and 2 respectively. The examination of the white mouse and one water rat was done independently of the survey.

? *Heligmosomum braziliense* Tr.

On one occasion in *E. norvegicus* small reddish coiled nematodes were found in the duodenum, which contained blood-stained material; on treatment with hot alcohol glycerine the worms remained fairly closely coiled. In the preliminary examination it was considered that they were probably the above species, but owing to an unfortunate accident the specimens were lost, and no specific identification could be carried out.

Strongyloides sp. ?

On one occasion in *Epimys norvegicus* worms were recorded which belonged to the above genus.

Hymenolepis diminuta Rud.

Johnston (1918) gives the percentage of infection with this parasite as follows: *Epimys rattus* 9.2%, *E. norvegicus* 14%, *Epimys rattus alexandrinus* 10% and *Mus musculus* 1.3%. Balfour (1922) found that 17.6% *Epimys rattus* and 28.4% *Epimys norvegicus* were infected.

In the present observations 36 *Epimys rattus* were found to be free of this parasite, although previously found infected (Nicoll); *Epimys rattus alexandrinus* 5, or 10.6%

of 47 examined; and *Epimys norvegicus* 29, or 21% of 138 examined; one *Hydromys chrysogaster* was infected, one examined. No record was kept of the relative length of the parasites obtained; the greatest number obtained from one rat was 30 in *E. norvegicus,* while 24, 20, 18 and 14 were obtained from this species. In *E. rattus alexandrinus* the greatest number was 13 worms; no rat was found with less than 8 worms.

Hymenolepis nana Sieb.

Synonym—*Hymenolepis murina* Duj.

Johnston (1918) found this parasite in 14% *E. norvegicus,* 7.5% *E. rattus,* 7.0% *E. rattus alexandrinus,* and 2.7% *Mus musculus.* Balfour (1922) found *H. nana-fraterna* in 17.6% *E. rattus* and 1.2% *E. norvegicus.* In the present observations 5, or 3.6% of 138 *E. norvegicus* and in 1, or 2.1% of 47 *E. rattus alexandrinus.*

Cysticercus fasciolaris R.

Of this parasite Johnston (1918) states that in Sydney rats, it was found rarely (3%) in *E. rattus alexandrinus;* but more commonly in *E. norvegicus* and *Mus musculus,* though even in these the percentage of infection was not high. Leidy (1879) in Philadelphia says that only 6 out of a total of 500 *E. norvegicus* were free of the cyst. Balfour (1922) found it on a number of occasions, but does not give the percentage or the species of rat in which it occurred. In North Queensland it was found in 18, or 2.93% of 614 *E. norvegicus* examined. The other species were found to be free of the cyst. In one instance a total of 24 cysts was found in various stages of growth; in others the number ranged from 6 to 16; and in one case 2 cysts only were recorded. No instances of the occurrence of liver sarcoma were recorded.

Multiple infections.

Numerous instances occurred in *E. norvegicus* and *alexandrinus* of double infections; this was the case also with *Hydromys chrysogaster,* in which *Ganguleterakis spumosa* and *Trichuris muris* occurred in fair numbers.

Table II. Shows the mixed infections with more than two species of parasites.

PATHOLOGICAL.

Cleland (1918) records the following tumours from rats and mice.

Epimys norvegicus. Squamous-celled epithelioma of the stomach. Double renal carcinoma of the kidney. Renal carcinoma of kidney. Renal carcinoma with metastases. Renal carcinoma of kidneys. Malignant hyponephromata of both kidneys. Carcinoma of the thyroid. Fibro-adenoma becoming adeno-carcinomatous, of the mammary gland. Fibro-sarcoma of the mammary area. Spindle celled sarcoma of the liver. Spindle celled sarcoma of the stomach. Large celled sarcoma of the chest.

Epimys norvegicus var albina. Ossifying sarcoma (?) in lungs, thymus over pleurae and ribs; pectoral muscles and inner muscles of thighs, attached to femur and near vertebral column in neighbourhood of kidneys and invading these.

Epimys rattus. Carcinoma of kidneys.

Mus musculus. Carcinoma of the mammary gland. Carcinoma of salivary glands and ? mammary gland.

The following innocent cyst about the size of a walnut was found in *E. rattus*:—Multilocular ovarian cyst.

In the present investigation only two definite growths were met with, both occurring in *E. norvegicus;* one of these was about ¾″ in diameter, of a fairly hard con-

TABLE II.

SPECIES OF RAT	No. of Rats	*Coccidia* Sp.	*Trypanosoma Lewisi*	Leprosy	*Hormorhynchus moniliformis*	*Hepaticola hepatica*	*Ganguleterakis spumosa*	*Syphacia obvelata*	*Gongylonema* Sp.	*Trichuris muris*	*Hymenolepis diminuta*	*Hymenolepis nana*	*Cysticercus fasciolaris*
E. norvegicus	1	...	X	...	X	...	..	..	X	...		.	...
"	1	..	...	...	X	...	...	...	...	X	X	...	...
"	1	...	...	...	...	X	X	...	...	...	X	...	...
"	1	..	...	...	X	...	..	...	...	...	X		X
"	1	...	X	..	X	...	...	...	X		...	...	...
"	1	X	X	...	...	...	...	...	...	X	...	...	...
"	1	...	...	...	...	X	...	...	X	...		.	X
"	1	...	...	...	...	X	...	...	...	X	X	..	...
"	1	...	..	...	...	...	...	...	...	X	X	X	...
"	1	...	X	..	X	...	X	...	...			..	...
E. rattus alexandrinus ...	1	...	...	...	...	...	.	...	X	X		X	...
E. norvegicus	1	. .	...	...	X	...	...	...	...	X	X	X	...
"	1	X	.	..	X	X	...	...	...	...	X	...	...
"	2	X	X	..	X	...	...	...	...	...	X	...	...
"	1	...	...	...	X	X	X	..	.	...	X	...	...
"	1	...	...	X	X	X	X	...	...	...	..	...	...
E. rattus alexandrinus ..	1	...	...	...	X	X	...	...	X	X	..	...	...

sistency, and was very lightly attached to the shoulder on the right side; on section it proved to be a Fibroma; the other growth was present on both feet on the upper surface, and had a wart-like appearance; macroscopically it appeared to be a papilloma; this material is being held over for further study. Beyond a few obvious cases of enlargement of the spleen no other abnormalities were noted.

PREGNANCIES.

Cleland (1918) in Perth during 1906-08, working almost exclusively with *Epimys rattus,* found that there was a definite variation in the percentage of pregnancies; during March 14.7% of the females were found to be pregnant; during April to May there was a fall from 10.1 to 9%; rising again in July to 15.7% and 20.3% in August; another fall to 13.6% occurred in September. From October to February it ranged between 21.2 to 35.3%.

Balfour (1922) states that pregnancies appeared to be commonest from April to June, with a second breeding period from September to November; during the former period he found 39.5% of females *E. norvegicus* pregnant. He says that July-August and December-January are off seasons.

In the present investigation, the source of error is probably increased owing to the small number examined monthly, the percentage of pregnant females in the monthly examinations from September, 1925, to the end of September, 1926, is as follows:—2.8%, 11.1%, 9.76%, 14.0%, 12.2%, 9.52%, 9.1%, 2.0%, 7.3%, 6.0%, 2.8%, 5.6% and 7.8%, giving an average over the whole period of 6.3%. The percentages are for the three species of rats and include 3 females of *Mus musculus* and 2 non-pregnant *Hydromys chrysogaster*.

TABLE III.

E. norvegicus.		*E. rattus.*		*E. rattus alexandrinus.*		*Mus musculus.*	
No. of foetuses.	No. of such pregnancies	No. of foetuses.	No of such pregnancies.	No. of foetuses.	No. of such pregnancies.	No. of foetuses	No. of such pregnancies.
3	2	...	...	...	...	...	..
4	3	4	2	4	2	...	...
5	2	...	...	5	7	5	1
6	2	6	2	6	5	...	..
7	1	7	2	7	11	...	..
8	8	8	2	8	9	...	.
9	3		..	9	3	...	..
10	3	..	...	10	1	...	.
11	3	...		.	..	.	..
15	1	...	...				.

Table III. shows the species examined, number of foetuses: and the number of such pregnancies.

Table IV. shows the number of rats of each species, for each month; the males and females present; the number of pregnant females and the foetuses found.

Since the above observations were concluded, a further 655 rats have been examined, 258 being *E. rattus alexandrinus,* of which 112 were males and 146 females; 10 females were pregnant, containing a total of 62 foetuses or 6.2 per pregnant female, a percentage of 6.85% of the females being pregnant; 67 were *E. rattus,* 29 males and 38 females, no pregnancies recorded; 330 were *E. norvegicus,* 147 males and 183 females, 9 females being pregnant, a total of 70 foetuses being present, giving 7.8 per pregnant female, and a percentage of pregnancies among the females of 4.9%; one female contained 15 foetuses.

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TABLE IV.

Species and Sex.	1925. Sept.	Oct.	Nov.	Dec.	1926. Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total	Remarks
Ep. norvegicus	46	31	38	37	14	50	53	40	34	86	90	39	56	614	Pregnant
♂	13	7	14	15	3	21	26	9	10	28	33	13	32	224	6.9%
♀	33	24	24	22	11	29	27	31	24	58	57	26	24	390	Foetuses
Pregnant	1	2	1	3	1	4	1	2	2	6	2	1	1	27	7.46
Foetus	10	14	11	17	3	40	7	7	12	48	14	8	10	201	per ♀
Ep. rattus	21	1	3	12	12	12	32	218	31	59	29	13	18	461	Pregnant
♂	7	0	1	3	0	4	8	51	12	23	11	5	7	132	2.4%
♀	14	1	2	9	12	8	24	167	19	36	18	8	11	329	Foetuses
[Pregnant	0	0	0	2	0	0	3	1	0	1	0	0	1	8	6.25
Foetus	0	0	0	14	0	0	19	7	0	6	0	0	4	50	per ♀
Ep. r. alexandrinus ..	55	52	19	55	46	34	64	129	45	60	54	27	56	696	Pregnant
♂	32	15	4	15	20	9	16	31	19	23	22	7	27	240	8.3%
♀	23	37	15	40	26	25	48	98	26	37	32	20	29	456	Foetuses
Pregnant	1	5	3	4	5	2	5	3	3	1	1	2	3	38	6.56
Foetus	5	40	18	29	36	13	37	18	21	7	4	15	16	249	per ♀
Mus musculus	0	1	0	1	0	1	0	0	0	0	0	0	0	3	Pregnant
♂ ...	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Foetuses
♀	0	1	0	1	0	1	0	0	0	0	0	0	0	3	5
Pregnant ..	0	0	0	1	0	0	0	0	0	0	0	0	0	1	per ♀
Foetus	0	0	0	5	0	0	0	0	0	0	0	0	0	5	
Hydromys chrysogaster ..	1	0	0	0	0	1	0	0	0	3	0	0	0	5	Nil
♂	0	0	0	0	0	1	0	0	0	2	0	0	0	3	
♀	1	0	0	0	0	0	0	0	0	1	0	0	0	2	Nil
Pregnant	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Foetus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Mixed Spp. ...	123	85	60	105	72	98	149	387	110	208	173	79	130	1779	Pregnant
♂	52	22	19	33	23	35	50	91	41	76	66	25	66	599	6.3%
♀	71	63	41	72	49	63	99	296	69	132	107	54	64	1180	Foetuses
Pregnant	2	7	4	10	6	6	9	6	5	8	3	3	5	74	6.95
Foetus ...	15	54	29	65	39	53	63	32	33	61	18	23	30	515	per ♀

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SWELLED HEAD IN MERINO RAMS.

AN UNFINISHED DESCRIPTION OF AN ENQUIRY INTO THIS CONDITION

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The term "Swelled Head" is applied by sheep owners to a condition occurring in young merino rams in the Western and North-Western districts of New South Wales. Whether it would occur in rams of other breeds is not known, since the merino is the breed exclusively maintained in those districts. The condition frequently terminates in death. Owners maintain that only rams are affected, but evidence shows that the special form of the disease from which it gets its local name is also seen in ewes and wethers. Furthermore, they state that the head is the only part of the body affected, whereas evidence has been obtained showing that "Swelling of the head" is only a special manifestation of a disease that is well known, and which shows itself in other forms of lesion. It is highly probable that, on account of the value of the rams, attention has been specially focussed on them while still alive or soon after death, and thus the striking and peculiar gross lesion has been observed quite readily. Rams are seen much more often than are the other members of the flock on a station; whereas ewes and wethers do not receive such close attention, so that the fact that any-

thing was wrong has not been observed until some time after death, when post mortem changes have caused bloating of the carcase. Moreover, since the number of deaths at a given period is not as a rule high, occasional deaths of ewes and wethers would not attract much attention among the thousands of sheep on a station, whereas the death of several stud rams, with a potential value running into four figures, would be discovered and commented upon immediately.

From time to time attempts have been made to ascertain the cause of "Swelled Head," and various agents have been charged by different workers with the offence. In one instance staphylococcus isolated from a case was claimed as the etiological factor. Others have considered the disease not to be microbic at all in origin, but really poisoning by some unknown plant. It is possible that the sporadic occurrence of the disease and the difficulty of obtaining suitable material, in the shape of a sick sheep, to work on, has largely accounted for the delay in arriving at a conclusion as to what the disease really was and what was the cause. On several occasions I have been asked to make some investigation into the cause of the trouble, and, before arriving on the station—some hundreds of miles from Sydney—have been informed that I should probably be unsuccessful in getting material, since no more sick or dead rams had recently been found. (It should be remembered, as already mentioned, that owners were very firm in the opinion that only rams are affected with this disease.)

The first occasion on which the writer came in actual touch with the condition was in 1923, when the representative of a large stud sheep station sought advice. He stated that young rams were dying on the station from "Swelled Head." Numerically the losses were not great,

but the value of the rams was such as to cause the owners concern. The losses had occurred annually on the station, but usually only an odd ram died from the complaint, though the numbers varied. No information could be obtained at the interview, which took place in Sydney, as to whether ewes or wethers were also affected; or whether the disease manifested itself in any other way than by swelling of the head. Once a ram showed distinct symptoms there was no recovery. The year 1923 was worse than usual as regards the incidence of "Swelled Head", and, furthermore, a local drought was being experienced, making hand feeding of the animals necessary. Again the manager considered that the disease was confined to the rams, though he stated that very few wethers were carried, and later correspondence showed that no one had troubled to ascertain closely whether any ewes were dying with similar symptoms, although it was known that ewes had died during the same period. It was the general opinion on the station that the cause of the trouble was dietetic (plant poisoning).

Upon request the head of a ram was sent to me in formalin. It presented what was afterwards found to be the typical appearance of "Swelled Head". The subcutaneous exudate was found to be only slightly tinged with blood. Occasionally a bacillus was found in the exudate, but, on account of the preservation in formalin, no culture or animal experiments could be carried out. Arrangements were made for obtaining fresh material, but, before further work could be carried out, the drought conditions necessitated the removal of the animals to other country, where the mortality quickly ceased. Nothing further was heard from this particular property, so one must conclude that the mortality had dropped to the average to which the owners had become accustomed for some years, and consequently their fears had become lulled.

In the winter the writer was approached by the breeder of valuable stud rams, situated a long distance from the above-mentioned case, with the object of discovering the cause of the trouble and endeavouring to find a means of prevention. The area of the station on which "Swelled Head" was occurring was about 400,000 acres, on which were running about 90,000 sheep. Of these about 4,500 were rams, 3,000 of the latter being young rams. The rams were run in special paddocks until the deaths had occurred that season, when they were moved. The disease had been seen for a number of years, but the number of deaths had not been such as to cause any undue anxiety, considering the number of sheep on the station. The disease did not occur in a dry year. The mortality does not continue all the year round. Losses are usually experienced in February, March and April, i.e., in the autumn. As a rule there are no losses from "Swelled Head" in October or November, but on the present occasion the losses had continued through May and June.

It was stated that the disease had seriously affected the sheep only during the past two years. But in this instance, as already pointed out, the owners were thinking mainly of the rams, and, on local investigation by the writer, circumstantial evidence was found to show that losses in ewes and other less valuable sheep had occurred from the same cause, but had been taken as a matter of ordinary station loss, or the deaths had been ascribed to some other condition. Furthermore, the owner stated that some years ago, about forty ewes had died in one paddock from what some held was the same disease as "Swelled Head". During 1922, '23 and '24 the special condition of "Swelled Head" had only been found in young rams. (Here it is again necessary to point out (i) that the condition was specially looked for only in the rams, and (ii) the huge

area of the station.) The ewes and the few wethers grazed in large paddocks, where they were only occasionally mustered; whilst the rams were kept in much smaller paddocks, where they were under constant supervision. The mortality caused uneasiness; but it was really on account of the value of the animals rather than the numbers; so that one can readily understand the opinion that the *disease*—not merely a particular symptom of it, namely, "Swelled Head"—was confined to the rams.

When the sheep were removed to other paddocks the deaths gradually ceased. This was also the case with the 3,000 young rams in 1924.

The country was flat, open, black-soil plains.

Swelled Head as seen in Rams.

The disease is most prevalent in rams of from ten to fourteen months of age, but it has been seen in ram lambs six months old. The mortality varies from year to year, but as a rule is not heavy, though the potential value of the young animals makes the financial losses appreciable. During 1923 and 1924, however, the death rate from this condition had been unusually heavy. In 1923, out of 4,000 rams, over 100—i.e., 2.5%—died from "Swelled Head"; whilst in 1924, in a flock of 2,500 rams, more than 70—i.e., 2.8%—died from the same cause. In the latter year the great majority of the animals were found dead; but in 1923 death did not occur so rapidly, so that more of the affected rams were seen alive.

Symptoms.

These agree with those observed by the writer and with the descriptions given by owners of other properties. They may, therefore, be taken as typical of "Swelled Head".

The affected animals walk with a stiff gait, the head being held in the air and the back arched. If they are

seen in an early stage there is no visible swelling of the face. (In this connection it should be observed that only parts of the face of merino rams are bare, most of it being covered with very thick wool, so that any swelling of the latter parts would not be observed visually until it had become very pronounced.) The next day the head is visibly swollen. The swelling appears to start about the arch of the nose, and then spreads around the face, lips and jaws. (Again, these areas are noticed particularly, perhaps, because they are bare.) It may extend to the orbits and render the animal unable to see. One manager, however, has seen the swelling affect the nose only. The swelling is very doughy and apparently not painful. In 1924 the rams died within 24 hours of discovery, but the previous year the disease took a more prolonged course. Unless the animal showed signs of a swelling about the head, it was considered to be affected by some other condition.

Animals had been autopsied by the owners, and the following were the points to which their attention was drawn:—

When the skin over the swelled head was incised, abundant fluid escaped. If the incision is made before death, this fluid is straw coloured, but if the incision is made immediately after death, the exudate is blood tinged. No particular odour has been observed. Both the thoracic cavity and the pericardial sac contain a considerable amount of blood-tinged fluid. No particular changes elsewhere have been noticed; but they were not specially looked for.

No systematic post mortem examination of any sheep on the station had been made, save of those dying from "Swelled Head". Consequently other lesions or dead sheep showing other lesions, have escaped observation. (This is important, in view of the writer's personal observations.)

At the time of the interview in Sydney, already mentioned, the mortality among the rams had dropped and the deaths were occurring at irregular intervals, but a visit was paid to the station at the first opportunity, and fortunately during that period enough fresh material and information were obtained to enable the elucidation of the problem as to the cause of the trouble.

In view of the expressed opinion, both professional and lay, that "Swelled Head" was due to poisoning by plants, special attention was paid to that feature. But the information given by the owners, and a close examination of the paddocks in which the disease had occurred in various years, as well as some in which it had never been seen, showed that the vegetation, which was what is known in Australia as "herbage", there being little or no grass, was the same in all of them. Moreover, the plants growing on the station in any appreciable quantity were all well known, and could not be implicated as being responsible for the trouble. There were a number of other factors also which indicated strongly that the condition was not one of plant poisoning, but they need not be explained further here.

The botanical examination of the station took some days, during which one or two deaths were reported, the young rams having been found dead in the morning. In view of the necessity in the case of sheep, where a disease of unknown cause was being investigated, of making sure that any organism found was present in the tissues or fluids of the body before death, these animals found dead were ignored for bacteriological purposes. It was then decided to round up the sheep every day, and, after examining them carefully in yards, to hold them there until the evening, when they could be released again. This procedure was successful. Two typical cases of "Swelled Head" were found, as well as one showing no swelling

of the head, but lesions typical of the organism to be described. Thus three rams were found affected with disease under which post mortem bacterial invasion was out of the question. Although the men riding the boundaries of the paddocks in which the ewes were living had instructions to report any found dead, none were observed during my stay at the station. This was not proof, however, that none had died in that period, for, in the case of very large paddocks, such as those in question, a sheep may die and its body lie for weeks without being seen, unless its presence is betrayed by the carrion crows, and no loss observed until the monthly muster and count, unless the number of dead is considerable.

The following are the protocols of the animals found affected:

Ram No. I.

Merino ram, aged about 12 months; in very good condition. Apparently quite well when last seen the previous night and in the morning. (The rams were not examined individually, that being impracticable in the case of several thousand, but they were closely observed as they were moving out of the yard and about the paddocks grazing. Such observation, however, by a skilled observer is quite sufficient to locate a sheep when it is distinctly ill.)

On the morning in question, whilst the rams were being driven to the yards, a ram was observed ill, but the driver did not particularly look for any swelling of the head. The ram quickly became so ill that it was left lying in the paddock some distance from the yards.

When the sheep was seen by the writer, it was practically comatose. It made no attempt to move on being handled. Its temperature was 105.4 Fahr. The respirations were very shallow. Pulse could not be felt. Mucous membranes

very congested. Its faeces were very loose and offensive in odour. The animal was brought to the yard, where it died a few minutes later. A post mortem examination was made immediately.

AUTOPSY.

The lower part of the head was considerably swollen and oedematous, i.e., especially around the nose, cheeks, upper and lower jaws and the intermaxillary space. On incision of the skin over these parts, the subcutaneous tissues were found greatly thickened and saturated with a blood-stained, odourless fluid, which drained away in large quantity. The submaxillary and pharyngeal lymphatic glands were deeply congested. The masseter muscles of the left side of the head were very dark in colour from haemorrhages, but they had no very distinct abnormal odour. The masseters of the right side were neither dark nor haemorrhagic. The gums of the lower jaw were of a leaden colour. No undue amount of fluid in the thoracic, abdominal or pericardial cavities. Lungs normal. A few endocardial petechiae in the right heart, but none in the left. Abdominal lymphatic glands congested. Kidneys, spleen and liver normal. There were a few petechiae on the mucous membrane of the fourth stomach, but no congestion. The first part of the duodenum was moderately congested, but the remainder of the intestine was normal.

The skin over the swollen face was thoroughly seared before incision with a sterile knife. Smears of the oedematous liquid showed an occasional bacillus. Smears from the affected masseter muscles showed a fairly large number of the same type of bacillus. Cultures from these parts, and from the heart blood, resulted in pure cultures of the bacillus to be described. No bacilli could be detected microscopically in the smear from heart blood or lymphatic glands. Pipettes of the oedematous fluid and heart blood

and portions of the masseter and organs were obtained after very strict precautions to prevent contamination, and reserved for laboratory examination.

An aged ram was inoculated subcutaneously on the inside of the thigh with 20 c.c. of blood taken straight from the heart of the dead ram within a few minutes after death. A large amount of blood was injected because it was more of a speculative inoculation.

On the next morning this ram was found lying down and refused to move. Its temperature was 105.6 Fahr. The inoculated leg was moderately swollen and oedematous, and the skin on the inside of the thigh very livid. At 4.0 p.m. the animal was killed. The swelling of the leg had become greater. Immediately before being killed the animal was unable to move, but was still conscious.

Autopsy.

The inoculated leg was swollen and oedematous from the thigh to the fetlock. The skin on the inside of the thigh was very livid and in parts had ruptured, a blood-tinged fluid escaping in droplets. On incision of the skin of the thigh, a good deal of blood-stained but odourless liquid escaped. The subcutaneous tissues of this region were saturated with this same fluid. The muscles underneath the affected part appeared little affected. Material was obtained under strict asepsis for further work.

Ram No. II.

On another morning, whilst the sheep were being mustered for bringing into the yards for classification, a ram was seen to be amiss. He did not move like a healthy sheep. When singled out from the flock he was seen to be lame in a hind leg. After a time he became so lame that it was difficult to get him along, and consequently he was left behind. On being examined about an hour

later, he was found to be dead. A post mortem examination was made at once.

AUTOPSY.

Ram aged two years. Condition very good. Rigor mortis marked. A green fluid running from the nostrils. There was no swelling of the head or its neighbourhood. The muscles of the face and throat were normal. On skinning, the right shoulder showed some discolouration with a moderate amount of subcutaneous blood-stained exudate. The skin on the inside of both thighs showed a moderately livid discolouration. Some of the muscles on the insides of both thighs were markedly discoloured and haemorrhagic, others were normal. The subcutaneous tissues of these areas were infiltrated with a blood-stained exudate with a distinct odour, but one hard to define. It was not putrid. On incision of the affected muscles they were found to be very dark in colour—some almost black—and haemorrhagic, but there was very little evidence of gas formation as shown by sponginess. The same indefinable odour was more pronounced, but it was not distinctly rancid.

On the left flank, and extending inwards to the peritoneum, was a lesion about the size of a hand, resembling a bruise. The abdominal viscera were normal. There was about 200 c.cs. of a blood-stained fluid in the pleural cavity, and the pericardium was moderately distended with the same kind of fluid. The lungs were normal. A number of endocardial haemorrhages were present in the right ventricle. Smears were made from various parts after thoroughly searing the skin before incision. Material was taken from exudates, muscle lesions, organs and heart blood under aseptic precautions, for bacteriological and cultural examination. The same bacillus was found as in Ram No. I in purity, from the lesions and subcutaneous exudate of

Ram No. II; but the heart blood was found to be contaminated with other organisms (agonal p.m. invaders). There was some doubt about the purity of the pleural exudate. Consequently that was not used for experimental work.

Ram No. III.

Aged about 14 months. Discovered ill when being mustered for inspection in the morning. When observed the animal was visibly ill. Its movements were listless, and it did not resent the blows of other rams or attempt to move out of the way. That part of the face which was free from wool was distinctly swollen, especially around the nose. Closer examination and palpation showed that the swelling extended practically all over that part of the head below the eyes, including the jaws and intermaxillary space, but not the orbits. The swelling was very doughy, not tense anywhere. There was only a little discolouration of the overlying skin, and some slight evidence of pain on palpation. Temperature, 104.5 F. Respirations hurried. By the late afternoon the animal had become so seriously ill that it was evident that it would not last out the night. Consequently it was killed and a post mortem examination was made at once.

Autopsy.

On incision of the skin of the face, copious fluid, odourless and only slightly blood-tinged, drained away. The subcutaneous tissues of the part were greatly thickened and saturated with the same fluid. The swelling did not extend beyond the head. The masseter and buccinator muscles of the left side were almost black and showed innumerable small haemorrhages. The gums and buccal mucous membrane of the left side were of a deep leaden colour. The affected muscles were rather dry and showed evidence of some gas formation by the dissociation of the

muscle fibres. There was a very distinct odour on incision of the affected muscles, but not particularly of a rancid nature. The other muscles of the head were apparently unaffected. The lymphatic glands of the head and throat were deeply congested, but those of the rest of the body showed no striking change. The pericardium was moderately distended with a straw-coloured, odourless liquid, but there was no abnormal amount in the pleural or peritoneal sacs. A few endocardial haemorrhages were present in the right ventricle. The lungs and abdominal organs appeared normal. Smears of liquid pipetted from the facial exudate, pericardial fluid and heart blood, as well as portions of the affected muscles and normal organs were obtained under the usual strict attention to details to avoid contamination.

Only a few bacilli were found in the facial exudate by microscopical examination, and none in the heart blood, pericardial fluid or organs. They were numerously present apparently in purity in the masseter and buccinator muscles. Cultures, both aerobic and anaerobic, from the heart blood, pericardial fluid and organs remained sterile. But from the facial exudate and the affected muscles the same bacillus as was obtained from Rams I and II, was obtained in purity.

In view of the amount of material obtained, not only from the three naturally affected cases, but also from the inoculated ram, it was concluded that sufficient had been obtained to conduct laboratory work upon. A few more deaths occurred after my departure from the station.

With the material obtained, most of which reached the laboratory uncontaminated, cultures, both aerobic and anaerobic, were made; animal inoculations were carried out with the original material and with cultures, as well

as the ordinary routine of microscopical examination. Aerobic cultivation was in all cases, except some obvious contaminations, negative. But anaerobic cultivation of material from the facial exudates and the affected muscles and heart blood resulted in the isolation in purity of a bacillus with which a series of animal experiments and cultural tests was carried out.

DESCRIPTIONS OF NINE NEW SPECIES OF EUCALYPTUS.

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(With Plate III.)

(*Read before the Royal Society of New South Wales, July* 6, 1927.)

SYNOPSIS.

1. *E. pygmaea,* Stringybark.
2. *E. deformis,* ,,
3. *E. aequans,* ,,
4. *E. globoidea,* ,,
5. *E. Callanii,* ,,
6. *E. Bottii,* Peppermint.
7. *E. Robertsoni,* ,,
8. *E. multicaulis,* Ash.
   All from N.S.W.
9. *E. Bleeseri,* Bloodwood.
   Northern Territory.

1. Eucalyptus pygmaea n. sp.

Mallee 2-6 pedes alta, caulibus aliquanto dense ramosis, ramulis quadrangularibus; folia juvenilia glabra, sessilia, elliptica vel ovata; folia matura alternata, petiolata, falcato-lanceolata, obscure viridia; gemmæ parvæ, cylindroido-clavatæ, obtusæ; antheræ reniformes; capsulæ sessiles, depresso-globulares, 8 x 10 mm.

A Mallee-like shrub, 2-6 feet high, with somewhat densely-branched stems, and quadrangular branchlets; juvenile leaves glabrous, sessile, elliptical to ovate; adult leaves alternate, petiolate, falcate-lanceolate, dark green; buds small, cylindroid-clavate, obtuse; anthers reniform; fruit sessile, depressed-globular, 8 x 10 mm.

A shrubby Mallee-like Stringybark, 2-6 feet high, with short branching stems ½ to 1½ ins. in diameter. Branchlets reddish, more or less quadrangular and sulcate, caused by the decurrent petioles.

Juvenile leaves glabrous, the first or lowest pair opposite, sessile or shortly petiolate, elliptical to broadly ovate, 5-10 cm. long, 3-9 cm. broad; veins distinct, the lateral ones more or less bifurcate, intramarginal vein distant from the edge. Internodes densely hispid with stellate hairs.

Intermediate leaves alternate, petiolate, obliquely-lanceolate, thick, coriaceous, venulose, 7-15 cm. long, 4-10 cm. broad; lateral veins distinct, often broken or irregular, spreading at an angle of 50-60° with the midrib, and uniting with the undulate intramarginal nerve 3-4 mm. from the thickened nerve-like margin.

Adult leaves alternate, petiolate, falcate-lanceolate to obliquely-lanceolate, with a long straight or uncinate point, usually a dark glossy green on both surfaces, 4-11 cm. long, 2-3 cm. broad, venulose, but the veins more conspicuous on the lower surface, the median nerve usually reddish and channelled above; lateral veins diverging at an angle of 50-60° with the midrib; the intramarginal vein closer to the margin on the lower half of the lamina than on the upper half.

Inflorescence in simple axillary umbels on compressed peduncles 10-13 mm. long, 3-4 mm. broad. Buds 8-15 in the head, sessile, yellowish, cylindroid-clavate, obtuse, slightly angular. Calyx-tube funnel-shaped or obconical; operculum blunt, hemispherical, much shorter than the calyx-tube.

Fruit sessile or nearly so, 8 x 10 mm. depressed globular, with a thick prominently raised disc, nearly as deep as the calycine portion and usually reddish, three or four celled, the small deltoid enclosed valves deciduous.

Range.—It seems to be restricted to a small area, about an acre in extent, on the top of a gravelly sandstone plateau, a little south of the 17 mile post between Hornsby and Galston, about 24 miles north by rail from Sydney, New South Wales.

Further extensions of its range may be looked for in somewhat similar situations, as the same class of country on which it grows extends for many miles along the coast range, both north and south of the locality indicated above. In company with Mr. D. W. C. Shiress I found this species in June, 1914, but could only obtain specimens of juvenile and intermediate leaves, as it was just recovering from the effects of a bush fire.

We paid several visits to the spot at different intervals, and succeeded in obtaining buds and fruits in June, 1922. Shortly afterwards it was again burnt down, and again two years afterwards when there was a good prospect of obtaining additional material.

Affinities.—1. With *E. Camfieldi* Maiden. I had several good opportunities of studying these species, as they grow side by side in small communities, and are somewhat similar in habit, being dwarf and Mallee-like, but they are entirely different in the shape of their juvenile leaves. The early leaves of *E. Camfieldi* are cordate and closely sessile, and remain opposite for an indefinite number of pairs, whereas the juvenile leaves of *E. pygmaea* are elliptical, shortly petiolate and opposite for two or three pairs; they are also much broader than those of *E. Camfieldi.* But the latter species exceeds the former in height and density of growth, it sometimes grows into small individual round-headed trees up to 12 feet high, with a stem diameter of 3-6 inches. The buds of *E. Camfieldi* are more globular than those of *E. pygmaea,* but the fruits are very much alike both in size and shape.

3. With *E. capitellata* Sm. The juvenile leaves of both species are not very dissimilar. On the whole, those of *E. capitellata* are the coarser of the two, while the buds are also larger, and more angular. The fruits are also larger and compressed to a greater degree than the fruits of *E. pygmaea*. On the other hand, *E. capitellata* is a tree, while *E. pygmaea* is a small, bushy Mallee.

2. E. DEFORMIS n. sp.

Stringybark Mallee vel arbor parva deformis, 6-25 pedes alta, 2-9 uncias in diametro; cortex laxe fibroso-intricatus; folia juvenilia opposita vel alternata, cordata, lanceolata, sessilia vel breviter petiolata, fere glabra, leviter crenulata, 2.5-6 x 1.7-4.5 cm.; folia matura alternata, petiolata, obliquo-falcata-lanceolata, 6-14 x 1.3 cm.; infloresentia umbellis axillaribus 5-14 florum, gemmae subsessiles, cylindracae, acutae vel rostratae, 7-8 x 3 mm.; antherae reniformes; stylus teres, subulatus; capsulae hemisphaericae ad fere globulares, subsessiles, 7-8 x 4 mm.; discus convexus admodum crassus.

A Mallee, or a small, somewhat deformed or badly-shaped Stringybark, 6-25 feet high, 3-9 in. in diameter, usually growing in moist, shallow sand-stone depressions, and on damp, stony plateaus and low ridges. Bark loosely matted-fibrous on the stem and main branches, the smaller branches less fibrous and usually dark-coloured.

Juvenile leaves cordate to lanceolate, sessile to shortly petiolate, only the first 2 or 4 pairs opposite, or sometimes an occasional pair may be opposite amongst the alternate ones, glabrous, except for a few glandular hairs along the midrib, dark green, the margins slightly crenulate, 2.5-6 cm. long, 1.7-4.5 cm. broad; lateral veins not numerous, usually somewhat prominent beneath, diverging at an angle of 40-50° with the midrib; intramarginal vein dis-

Eucalyptus multicaulis, Blakely.

Eucalyptus deformis, Blakely.

tant from the edge. Stems scabrous with stellate hairs for 6-12 inches, then smooth.

Intermediate leaves alternate, petiolate, oblong-ovate to obliquely lanceolate, mucronate, glabrous, dark green, 5-8 cm. x 2-6 cm.; veins somewhat obscure, the lateral ones spreading at an angle of 50-60° with the midrib; intramarginal vein undulate, usually distant from the thickened nerve-like margin.

Adult leaves alternate, petiolate, obliquely lanceolate, or falcate-lanceolate, thick, coriaceous, dark green, glossy, 6-14 cm. x 1-3 cm. Venation penninerved, usually distinct; lateral veins diverging at an angle of 30-35° with the midrib, the median nerve very distinct on both sides, and usually closer to the lower margin; intramarginal vein usually very close to the edge.

Inflorescence in axillary umbels, the peduncle compressed, 5-7 mm. long, supporting 5-14 smallish flowers. Buds elongated, acute, to slightly rostrate, sessile or nearly so, somewhat angular at the base, 7-8 mm. x 3 mm. Operculum conoid or rostrate, as long as or longer than the narrow, funnel-shaped calyx-tube. Filaments not numerous, white, many of the upper ones straight in the bud or before the operculum falls, and nearly as long as the terete, subulate style. Anthers small, reniform.

Fruit sessile or very shortly pedicellate, hemispherical to nearly globular, 7-8 x 4-6 mm.; disc usually prominent, forming a rather broad, smooth, slightly convex band around the small orifice, valves small, scarcely exsert.

Timber.—The trees are small and usually hollow and produce a very pale brown, hard and durable timber, but it is so small that it is of little use except for fuel or mine props.

Affinities.—1. With *E. eugenioides,* from which it differs in being a Mallee or dwarf tree, in the broader and more glabrous suckers, and in the more sessile and thicker fruits.

2. With *E. agglomerata.* The suckers of this species in the young state are softly hairy, while those of *E. deformis* are scarcely hairy; they are also smaller and they do not possess the putrid-like odour of *E. agglomerata.* The latter is also a large tree, whereas the former does not appear to exceed 25 feet in height, and the stem diameter is usually less than 12 inches.

3. With *E. globoidea.* Both species have broad juvenile leaves, but those of *E. deformis* appear to be more cordate-lanceolate and more variable than the juvenile leaves of *E. globoidea.* The buds of the latter are also smaller than those of the former, and the operculum is also shorter.

The fruits of *E. globoidea* are also smaller and rounder than the fruits of *E. deformis.* There is also a marked difference in the habit of the trees: *E. globoidea* is a small to medium-sized single-stemmed tree of good shape, while *E. deformis* is usually a Mallee or a badly-shaped tree. The former seems to prefer a clay soil, while the latter is strictly a sandstone species.

Range.—So far it has been found only on the rough sandstone country south and north of the Lower Hawkesbury River, New South Wales, and is very common from Berowra to the Hawkesbury on the southern side, while on the northern side it extends as far as Penang Range, Gosford. It is very plentiful in the vicinity of Kariong Trig. Station, the type locality, which is roughly about 7 miles north of Brooklyn. (D. W. C. Shiress and W.F.B.)

3. E. AEQUANS n. sp.

Stringybark parva ad 10 pedes alta; cortex fibrosus; ramuli rubelli, compressi vel teretes, glandulari-scabrosi;

folia juvenilia opposita vel alternata, ovata vel lanceolata, sessilia vel nonnumquam breviter petiolata; folia matura alternata petiolata, oblonga vel angusto-lanceolata, *aequilateralia,* uncinata; gemmae in parvis umbellulis, sessiles, graciles, cylindroideae, acutae, 5-6 mm. longae; antherae reniformes; capsula sessilis, fere globularis, truncata, 3-4 cellis, 5 mm. longa, 6 mm. diametro.

A small Stringybark up to 10 feet high, sometimes branching at the base, and with the same general appearance of *E. Moorei.* Bark somewhat flat and flaky-fibrous on the stem, more or less smooth and of a dull greenish-grey colour on the branches. Branchlets reddish, at first compressed but soon becoming terete, and more or less glandular-scabrous. Young tips somewhat metallic, of a bluish cast.

Juvenile leaves ovate-lanceolate to lanceolate, only the first two or three pairs opposite, sessile to shortly petiolate, glabrous except the revolute, minutely glandular, denticulate margins, pale green above, dark green and glandular-scabrous beneath, 2-4.5 cm. long, 1-1.5 cm. broad. Venation penninerved, somewhat obscure, the median nerve slightly convex beneath, compressed or slightly channelled above; lateral veins very fine, scarcely visible on the upper surface, the intramarginal vein close to the edge. Stems and internodes reddish-brown, scabrous, with numerous glands tipped with microscopic stellate hairs.

Intermediate leaves not seen in a fully developed state, alternate, shortly petiolate, lanceolate to obliquely-lanceolate with acuminate points, up to 5 cm. long, 2 cm. broad.

Adult leaves alternate, somewhat rigid, oblong to narrow-lanceolate, usually terminating in a fine uncinate point and gradually diminishing at the base into a rather short, slightly compressed petiole, thick, coriaceous, flat, *aequi-*

lateral and glossy on both sides, somewhat scabrous with numerous, more or less conspicuous oil-glands, 3.5-8.5 cm. long, 7-13 mm. broad. Venation penninerved somewhat obscure, the median nerve faintly canaliculate on both surfaces; lateral veins sometimes more or less distinct, not more than three or four prominent ones on each side of the midrib and usually radiating at an angle of 10-20° with the median nerve, the intramarginal· vein usually distant from the nerve-like margin.

Inflorescence in short axillary umbels of 5-9 small sessile flowers; peduncle compressed or almost terete, glandular scabrous, slightly dilated at the top, 4-5 mm. long. Buds sessile or nearly so, slender, cylindroid, acute, 5-6 mm. long, about 2 mm. in diameter. Calyx hyprocrateriform, rather thick, slightly longer than the acutely conoid glossy operculum; filaments not numerous, nearly all antheriferous. Anthers reniform, with broad cells and a very small terminal gland.

Fruit sessile, almost globular, truncate, with a somewhat slightly convex disc, 3-4 celled, the very short deltoid valves enclosed or sometimes slightly protruding beyond the broad orifice, 5 x 6 mm.

Fertile seeds black, obliquely pyramidal to somewhat navicular, bi or tricostate on the face, the dorsal surface smooth and striate. Hilum terminal, small, whitish, 2-2½ mm. x 1-2 mm. Sterile seeds light brown, granular, striate, usually smaller than the fertile seeds.

This species has remarkably uniform and equal-sided leaves for a Stringybark, hence the specific name.

Range.—Only known from King's Tableland, Wentworth Falls, Blue Mountains, N.S.W., where it grows in association with other small species such as *E. Moorei*, *E. ligus-*

trina, and *E. stricta.* (D. W. C. Shiress and W. F. Blakely.)

Affinities.—1. With *E. ligustrina* D.C. Both are dwarf species, but *E. aequans* seems to differ from *E. ligustrina* in every character except in the shape of the fruits. The small dainty cordate juvenile leaves of *E. ligustrina* are very dissimilar from the lanceolate juvenile leaves of *E. aequans.*

2. With *E. Kybeanensis* Maiden and Cambage. This is also a dwarf species, with narrow leaves, but the buds are almost globular and not cylindrical and acute like the buds of *E. aequans.* The fruits of the latter are also smaller and thinner than those of the former.

4. E. GLOBOIDEA n. sp.

Stringybark parva 20-40 pedes alta; cortex stispis crassus, fibrosus, persistens, ramis glabis; folia juvenilia alternata, obliquo-lanceolata, vel falcato-lanceolata, tenuia, 6-12 x 1.5-4.5 cm.; infloresentia umbellis simplicibus axillaribus 6-16 florum; gemmae cylindricae, acutae; calyx obconicus; operculum conicum, acutum vel rostratum, 8 x 3 mm.; antherae reniformes; capsulae hemisphaericae, in parvis globularibus capitibus congregatae, ad 15 mm. diametro.

A small to medium-sized Stringybark, 20-50 feet high, with a short, straight stem and spreading branches, which give the tree a round-headed appearance. Bark rather thick, fibrous, a typical Stringybark; branchlets semiterete.

Juvenile leaves not seen in the earliest stage, alternate, ovate, lanceolate, shortly petiolate, glabrous or nearly so, 2.5-5 cm. long, 1.5-2.5 cm. broad, or broader, rather thick, smooth, with entire margins. Venation somewhat obscure.

Intermediate leaves alternate, rather broad, petiolate, oblong, elliptical to obliquely-lanceolate, acute or mucronate, smooth and shiny on both sides, 5-8 cm. long, 3-5 cm. broad. Venation somewhat prominent, the median nerve conspicuous on both surfaces, the lateral veins rather numerous, diverging at an angle of 40-50° with the midrib; intramarginal vein very remote from the edge.

Adult leaves alternate, very variable, broad to narrow-lanceolate, or obliquely-lanceolate, to falcate-lanceolate, thin, coriaceous, shiny on both surfaces, 6-12 cm. long, 1.5-4.5 cm. broad. Veins distinct, the lateral ones very slender, radiating at an angle of 30-50° with the midrib, the intramarginal vein distant from the edge in the broad leaves, rather close to the margin in the narrow ones.

Inflorescence in simple axillary umbels, the peduncle rather slender, sometimes very short, supporting 6-16 flowers. Buds tip-cat shaped, acute or slightly obtuse, including the short pedicels about 8 mm. long, 3 mm. in diameter. Calyx funnel-shaped; operculum acutely conical, as long as or longer than the calyx-tube. Anthers reniform with rather narrow cells and a small terminal gland in front.

Fruit hemispherical or nearly so, rather small, usually in dense globular heads, up to 15 mm. in diameter, pale-coloured, except the smooth, reddish-brown slightly convex disc, 5-6 x 7-8 mm.; the cells very small, usually 4, with minute deciduous valves.

Timber pale, almost white, free in the grain and to all appearance as strong as the timber of *E. eugenioides*.

Range.—In the present state of our knowledge it appears to be confined mainly to the coastal districts and southern tablelands of New South Wales. The following are the localities:—

Bermagui (W. Hutchinson); Mt. Imlay near Eden. "One of the few Eucalypts found on the summit of the Mount. It reaches to but small tree on the top, but at the base of the Mount and some distance from it, the trees become normal, or average about 50 feet high." (J. L. Boorman); Kangaloon; "Stringybark saplings" (J. L. Bruce); between Eden and Brown Mountain (C. C. Robertson and W. A. W. de Beuzeville). The juvenile leaves are broad and of a very dark green. Illawarra (Rev. Dr. W. W. Woolls); Wingello (J. H. Maiden and J. L. Boorman, A. Murphy); Marulan (A. Murphy); Berrima (J. H. Maiden, J. L. Boorman, D. W. C. Shiress); Cutaway Hill, Mittagong (D. W. C. Shiress and W.F.B.). Co-type: Mount Colah (W.F.B.); Asquith (W.F.B.); Wyee (A. Murphy); Wallsend (J. L. Boorman, W. W. Froggatt); Booral (A. Rudder); Glen Innes (per Forestry Commission).

Illustrations.—It is depicted in the Critical Revision of the Genus Eucalyptus, under *Euc. capitellata,* Plate 38, figs. 7a, 7b, The type; also under *Euc. eugenioides,* Plate 40, figs. 14a, 14b, 14c; 15a, 15b, 15c. Fruit more globular than the preceding.

Affinities.—1. With *E. eugenioides* Sieber. It appears to be a smaller tree than *E. eugenioides,* with broader juvenile and adult leaves; the former leaves are also less stellate-hispid in the sucker stage, while the fruits are sessile and usually form small globular masses in contradistinction to the lax fruiting habit of *E. eugenioides.*

2. With *E. agglomerata* Maiden. Both species have broad juvenile leaves and conglomerate fruits, but the juvenile leaves of *E. globoidea* are smaller and more glabrous than those of *E. agglomerata,* while the fruits are smaller and relatively more uniform than the fruits of the latter species. It is also a much smaller tree than *E.*

agglomerata. The seedlings are also smaller and slightly more crinkled than those of the latter species.

5. E. CALLANII n. sp.

Stringybark gracilis, 20-50 pedes alta; folia juvenilia lata, oblique-ovata, breviter, petiolata, venulosa; folia matura nitida, angusta vel lato-lanceolata, venulosa; gemmae ovoido-clavata, operculo conico, tubo calycis obconico; antheræ reniformes; capsulæ pedicellatæ, hemisphaericæ, 5 x 5 mm., valvis brevissimis deltoideis in apertura inclusis.

A slender Stringybark, 20-50 feet high; juvenile leaves broad, obliquely-ovate, shortly petiolate, venulose; adult leaves glossy, narrow to broad-lanceolate, venulose; buds ovoid-clavate, operculum conical, calyx-tube obconical; anthers reniform; fruit pedicellate, hemispherical, 5 x 5 mm.; the very short deltoid valves enclosed in the orifice.

A Stringybark, with a rather flat, flaky-fibrous bark on the trunk, and a moderately smooth bark on the branches.

Juvenile leaves not seen in the very earliest stage, glabrous, and not stellate-hairy as in *E. eugenioides*, obliquely ovate, shortly petiolate, coriaceous, light green and somewhat rough with prominent veins and veinlets, 4-8 cm. long, 2.5-5 cm. broad, lateral veins somewhat irregular and bifurcate, diverging at an angle of about 50-60° with the midrib. Intramarginal vein undulate and usually distant from the edge.

Intermediate leaves alternate, broad-lanceolate to obliquely lanceolate on rather slender, channelled petioles, 6-16 cm. long, 3-5 cm. broad. Venation prominently raised on the lower surface, the lateral veins few and distant, the lower veins usually somewhat semi-longitudinal and sometimes uniting with the intramarginal vein about half-way up the lamina, diverging at an angle of 20-30° with the

midrib; intramarginal vein 3-5 mm. from the edge, the intervening space usually strengthened by a secondary marginal nerve.

Adult leaves alternate, petiolate, lanceolate, aequilateral or nearly so, slightly viscid and glossy on both surfaces, rather flat, 4-15 cm. long, 1-3.5 cm. broad, distinctly veined on the lower surface, obscurely veined on the upper; lateral veins radiating at an angle of 10-20° with the midrib. Petioles slender, moderately long and usually twisted.

Inflorescence in small axillary umbels, the common peduncle subterete, 8-12 mm. long, supporting 5-12 shortly pedicellate flowers. Buds ovoid-clavate, acute or the operculum acutely conical, 5 mm. long; calyx-tube short, obconical. Anthers reniform, the short filament adnate at the base, the broad cells crowned with a large globular gland.

Fruit pedicellate, hemispherical to cupular, the disc flat or slightly convex, darker than the calycine portion, 3 or 4 celled, 5 x 5 mm. or sometimes larger, the very short deltoid valves scarcely exsert.

Timber white, inclined to be gummy, fissile.

Illustrations.—A figure of this species will appear in the Critical Revision of the Genus Eucalyptus, by the late J. H. Maiden, Part LXXI., Plate 289, figs. 8-11.

I have pleasure in associating this uncommon species with the name of Mr. and Mrs. Albert Philip Callan, of "Grantham," Mittagong, whose kind hospitality led to its discovery, as also to another new species.

Range.—Up to the present it has been collected between Mittagong and Wombeyan Caves, and at Marrangaroo, New South Wales. The following are the definite localities:—

Back of Chalybeate Spring, near the Gib, Mittagong (D. W. C. Shiress, January, 1922). Bowral-Berrima road, about 3½ miles from Mittagong (same collector, April, 1920).

Bowral-Wombeyan Caves road, near the junction of the old Mittagong and Joadja roads (D.W.C.S., April, 1922). In April, 1923, I visited the same locality, accompanied by Mr. Shiress, and obtained specimens, which constitute the type. The trees were growing in poor white pipe clay-like soil, and resembled *E. eugenioides* in general appearance except that the bark is flatter and in broad strips, extending nearly to the branches, and not rough and fibrous throughout like *E. eugenioides.* One mile west of Wingello, small patches on poor clay soil (W. Murphy, August, 1924). "Three miles south of Marulan on the side of a gravelly ridge. Bark smooth except on trunk, black flaky bark" (Andrew Murphy, March, 1905). 18 miles from Wombeyan Caves, Bullio to Wombeyan (J. H. Maiden, October, 1905).

Marrangaroo, 102 miles west of Sydney (Dr. E. C. Chisholm, October, 1922). The leaves and buds are identical with those of *E. Callanii,* but the bark appears to be less fibrous, except at the base. It is a young tree, and therefore the bark is not mature.

Affinities.—1. With *E. Laseroni* R. T. Baker. Both species are small Stringybarks with almost the same cortical characters, but the branches of *E. Laseroni* are usually smooth and gum-like, and the leaves are broader and have a different venation from those of *E. Callanii.* There are also essential distinctions in the buds and fruits of both species. The half-developed buds of *E. Laseroni* are narrower and more stellate, and when mature are more clavate than the buds of *E. Callanii.* The fruits of the former are more depressed than the fruits of the latter, while the

timber of *E. Laseroni* is yellowish-brown, that of *E. Callanii* white.

Geographically the species are widely separated. *E. Laseroni* is found nearly 400 miles north of Sydney, and it appears to prefer a better class of soil than *E. Callanii*.

2. With *E. eugenioides* Sieb. *E. Callanii* is a smaller tree than the typical *E. eugenioides*, and it has a more compressed flaky-fibrous bark on the trunk only, which does not stand out in longitudinal ridges like the bark of *E. eugenioides*. The timber is also dissimilar and inferior to that of *E. eugenioides*. The buds and fruits of both species are, however, almost identical, but there is considerable diversity between the juvenile leaves of both species. Those of *E. eugenioides* are narrow, crinkled and stellate, whilst the juvenile leaves of *E. Callanii* are broad and comparatively smooth.

3. With *E. vitrea* R. T. Baker. The similarity of these trees is chiefly in the venation of their leaves, but the lateral veins of *E. vitrea* are even more longitudinal than those of *E. Callanii*. The floral organs, bark and juvenile leaves, of course, sharply separate them.

6. E. Bottii n. sp.

Arbor admodum magna, cortice caulis aspero plus minus rugoso, cortice ramorum glabro; folia juvenilia subglauca, lanceolata vel oblique lanceolata; folia matura falcato-lanceolata, undulata; gemmae parvae, rostratae; antherae reniformes; capsulae ovoidae, glandulari-rugosae, 9 x 8 mm.

A moderately large tree, 50 to over 100 feet high, with rough, more or less deeply-furrowed bark on trunk, smooth on the branches; juvenile leaves subglaucous, lanceolate to obliquely lanceolate; adult leaves falcate-lanceolate, undulate; buds small, rostrate; anthers reniform; fruit ovoid, glandular-rugose, 9 x 8 mm.

Juvenile leaves opposite for 3-6 pairs, slightly glaucous and somewhat rough with numerous oil-glands, lanceolate to obliquely lanceolate, shortly petiolate, very thin, dark green above, pale beneath, 4-7 cm. long, 2½-4 cm. broad; venation moderately distinct on both surfaces, but more prominent beneath, lateral veins diverging at an angle of 50-60° with the midrib, and uniting with the intramarginal vein a short distance from the edge.

Intermediate leaves alternate, slightly more glaucous than the juvenile leaves, and particularly the internodes which are glaucous to pruinose, green above, much paler beneath, broadly elliptical or obliquely-elliptical, or the upper ones obliquely-lanceolate, undulate with a short, terete glandular petiole, 9-16 cm. long, 5-9 cm. broad; venation distinct, the lateral veins rather distant, rising at an angle of 40-60° to the midrib; intramarginal vein very irregular, in some places it is close to the margin, in others 10 mm. from it, and when the latter, there is a rudimentary or very fine secondary intramarginal vein between it and the minutely crenulated margin.

Adult leaves alternate, petiolate, falcate-lanceolate to obliquely lanceolate, undulate, somewhat thick, coriaceous, smooth on both surfaces and with a very fine obscure venation, 6-16 cm. long, 1-3 cm. broad, the midrib slightly raised beneath, finely canaliculate above; lateral veins very fine, radiating at an angle of about 30-40° with the midrib; intramarginal vein a short distance from the slightly revolute margin. Petioles often twisted, glandular-rugose, convex beneath, channelled above.

Inflorescence axillary usually in simple umbels, but sometimes in short panicles. Umbels usually dense, the common peduncle compressed, 10-17 mm. long, bearing 7 to over 20 pedicellate flowers. Buds pedicellate, small, rostrate, the

calyx-tube obconical, thin minutely glandular-rugose, about 4 x 3 mm.; operculum conical but usually acutely rostrate up to 4 mm. long, striate on the inside; pedicels about 5 mm. long. Anthers reniform, the white filaments all fertile. Style subulate, more than twice the length of the calyx-tube.

Fruit pedicellate, forming ball-like masses up to 20 in the head, ovoid, glandular-rugulose, the small orifice surrounded by a rudimentary disc, the very small valves enclosed or sometimes flush with the edge of the disc 9 x 8 mm. Pedicels subterete, rugose, 4-5 mm. long.

Timber with a rather thick sapwood, pale brown when freshly cut, slightly gummy, moderately hard and with a more interlocked grain than the timber of *E. piperita*. It appears to be a superior timber to that of the latter species.

Named in honour of Harold Bott, my friend and companion on many botanical excursions during the last fourteen years.

Range.—So far it appears to be confined to a small area of the coast districts of the Counties of Cumberland and Northumberland at no great distance south and north of Sydney, N.S.W.

The following are the localities:—

Between Stanwell Park and Otford, large spreading tree with slightly glaucous undulate adult leaves (W.F.B.).

Oatley and National Park (J. H. Camfield, April, 1901); the fruits from Oatley are slightly larger and thicker than the type. Gladesville (H. Deane, June, 1886). Cedar Gully, Cowan. Tall, straight trees up to 100 feet high and 2 feet in diameter, growing in association with *E. agglomerata*, on rich clay soil (Blakely, Shiress, and Bott).

At the foot of Mt. Penang and along the old Penang road for some distance; also in Kendall's Glen, which is on the left of the Penang road going west from Gosford. Trees 50 to over 100 feet high, somewhat like E. *pilularis* in appearance, with straight boles covered with a rather thick, grey Peppermint-like bark extending to the base of the large branches on moderately young trees, and on old trees extending to the small branches. The top portion of very young saplings is somewhat pruinose, like those of *E. Sieberiana,* and the leaves are large, slightly glaucous and distinctly undulate. At one spot it is ecologically associated with *E. paniculata, E. pilularis, E. saligna*, and *Angophora intermedia.* Very old trees of *E. Bottii* are markedly like old trees of *A. intermedia,* both in general appearance and in cortical characters. The rough, grey bark of the former persists well out on the branches like the bark of the *Angophora* (W.F.B., H. Bott, and D. W. C. Shiress). Between Teralba and Fassifern, also about one mile south of Awaba (W.F.B.). Narara, on the edge of the "Brush" (W.F.B., D.W.C.S., and A. Murphy).

Affinities.—1. With *E. piperita* Sm. It is quite obvious that there are imperceptible gradations between *E. Bottii* and *E. piperita* and its allies, but the main difference between them is in the superior size, and more shaft-like habit of *E. Bottii* with its relatively better timber; in the broader subglaucous juvenile and intermediate leaves, as compared with the very thin light-green leaves with their pale undersurface of *E. piperita;* and in the slightly pruinose bloom of the very young saplings of the former, and also with its more rostrate buds, and less urceolate thick fruits. *E. Bottii* seems also to prefer a better class of soil, and low-lying land with a porous subsoil, whilst *E. piperita*, almost without exception, sticks to the well-drained, rugged sandstone country, particularly with a southerly aspect,

thus indicating that it prefers the cool side of the hills; at times it descends into the deep gullies until it meets with the shale, which seems to be a barrier to its progress.

2. With *E. pilularis* Sm. Young saplings of *E. Bottii* are tall and straight, and somewhat difficult to distinguish from saplings of *E. pilularis* with which it is often associated, and they are sometimes cut for the latter species. The timber of *E. Bottii* is darker than that of *E. pilularis* and much shorter in the grain. The adult foliage is also narrower and more glaucous than that of *E. pilularis,* while the juvenile leaves are very broad in comparison with those of *E. pilularis.*

7. E. Robertsoni n. sp.

Arbor permagna ad 180 pedes alta, 1-6 pedes diametro metrens; cortex stispis dense fibrosus atque intertextus; rami glabri; folia juvenilia opposita, angusto-vel late-lanceolata, acuminata, sessilia nunc amplexicaulia, parvum glauca, 1.5-10 cm. longa, 9-30 mm. lata; folia matura alternata, petiolata, angusto-vel late lanceolata, tenuia, exsiccata viridi-glauca, 7-17 cm. longa, 1.5-3 cm. lata; pedunculi axillares fulcientes 9-21 parvos flores; gemmae pedicellatae, clavatae vel rostratae; antherae reniformes; capsulae hemisphaericae vel pyriformes, truncatae, pedicellatae, 5-7 x 5-6 mm., disco obliquo vel horizontali, valvis parvis, inclusis.

A large tree up to 180 feet high, up to 6 feet in diameter. Bark close, not ribbony (Robertson), of the Peppermint type, branches usually smooth. Young branchlets compressed but becoming terete with age, usually of a reddish-brown colour or sometimes slightly pruinose. Leaves a pale slaty-green, usually with reddish veins and veinlets.

Juvenile leaves opposite for an indefinite number of pairs, narrow to broad-lanceolate, a few oblong-lanceolate, acuminate, sessile to stem-clasping, a much darker green

above than on the under surface, invariably drying a pale slaty-green colour, 1.5-10 cm. long, 9-30 mm. broad or broader; venation moderately distinct, the median nerve very prominent beneath, usually of a reddish-brown colour and somewhat thickened at the base, very fine and channelled above; lateral veins very fine, scarcely raised above the surface of the lamina, radiating at an angle of 30-40° with the midrib, and with numerous fine secondary veins; intramarginal vein usually distant from the edge. Oil dots very numerous, the larger ones less numerous than the small ones. Internodes terete, glandular, reddish-brown.

Intermediate leaves alternate, shortly petiolate, narrow to broad-lanceolate or falcate-lanceolate, acuminate, oblique or rounded at the base, drying a pale slaty-green on both surfaces, 3-10 cm. long, 1-4 cm. broad; venation somewhat similar to that of the juvenile leaves; secondary veins diverging at an angle of 25-40° with the midrib.

Adult leaves alternate, usually with slightly compressed petioles 1-2.5 cm. long, narrow to broad-lanceolate, obliquely-lanceolate and falcate-lanceolate, thin, drying a pale slaty-green, 7-17 cm. long, 1.5-3 cm. broad; venation sometimes very distinct, the median nerve reddish brown, slightly raised on both surfaces towards the base, or sometimes faintly canaliculate above; lateral veins numerous, diverging at an angle of 20-30° with the midrib, usually much branched and unequal in length; intramarginal vein very irregular and sometimes well removed from the margin owing to the abbreviated lateral veins, oil-dots conspicuous, very numerous.

Inflorescence in axillary umbels, the peduncle compressed, supporting 9-21 small pedicellate flowers. Buds clavate to rostrate, glandular, slightly glaucous, including the usually filiform pedicel 6-9 mm. long, about 3 mm. in

diameter. Calyx-tube funnel-shaped; operculum conical to rostrate or acuminate, sometimes longer and broader than the calyx-tube. Anthers reniform with rather broad lateral cells and a fairly large terminal gland.

Fruit clavate to pyriform, occasionally somewhat mallet-shaped, truncate, smooth or more often slightly rugose, pedicellate, sometimes the pedicels filiform as in *E. numerosa,* 5-7 mm. long, 5-6 mm. in diameter. disc oblique or forming a flat, broadish band over the very small enclosed valves, cells usually three.

Timber pale, with a slight pink tinge when fresh, changing to a very pale yellowish-brown when dry, moderately light, with a fairly long somewhat open grain, interspersed with short gum veins. It is fairly fissile and apparently not suitable for heavy work, and is inferior to Blackbutt, *E. pilularis,* but a superior timber to *E. radiata* or *E. numerosa.* Mr. C. C. Robertson, M.F., in "A Reconnaissance of the Forest Trees of Australia, from the point of view of their cultivation in South Africa," page [illegible]89, states that "on the high mountains above Tumut, etc., it is a large tree up to at least 120 feet high and commonly 3 or 4 feet, sometimes 6 feet, in diameter."

"The wood of this large timber tree on these mountains is regarded locally as good for buildings, including flooring and lining, and it is stated not to shrink or warp to any large extent. I even saw some good moulding of it which had kept its shape very well. It is a moderately light, strong wood and is excellent and largely used for pick-handles. It has gum veins but not to a very serious extent. It has also been used for furniture. It is also said to be quite durable, and house-blocks of it are believed to have lasted 40 years. A trial of it for railway sleepers has been arranged. I was told also in Victoria of this tree

being considered durable, fence posts of it having lasted 35 years."

Illustrations.—It is figured in Maiden's Critical Revision of the Genus Eucalyptus, Part vi, Plate 29, under *E. amygdalina,* fig. 8a, juvenile leaves; 8b, fruits, from Munendel Hill, Victoria (A. W. Howitt). Also Plate 30, under *E. amygdalina,* Labill., var *E. numerosa,* var nov. (1), and allies, fig. 3a, leaf; 3b, small fruits, from Lilydale, Victoria (A. W. Howitt); 4a, broad leaf; 4b, fruits, Darlimurla, Victoria (H. Deane). The late Mr. Maiden has a note: "This form undoubtedly shows affinity to var *numerosa.*"

Named in honour of Mr. C. C. Robertson, M.F., Forest Department, Pretoria, South Africa, who assisted in segregating this species from its allies.

Synonyms.—*E. amygdalina* of many authors, but not of Labill. *E. numerosa* Maiden (partim). *E. Australiana* Baker and Smith (partim). *E. phellandra* Baker and Smith (partim).

The late J. H. Maiden, and Messrs. Baker and Smith, referred certain specimens of *E. Robertsoni* to the above species, but they did not describe them.

Range.—It appears to be confined to Victoria and New South Wales. In the latter State it is wide-spread throughout the high mountain ranges from the Victorian border to Canberra, and it extends northward to Mullion Creek, Orange district.

Victoria.—Lilydale (A. W. Howitt). Mount Macedon (W. S. Brownscombe). Boggy Creek, Buchan-road (J. H. Maiden). Stony Creek, Dargo (A. W. Howitt). "Peppermint", near the Big River on the new road between Omeo and Glen Wills. Up to 3 or 3½ feet in diameter (H. Hopkins). Bulgaback, North Gippsland (A. W. Howitt).

New South Wales.—Grows into large trees on granite and basalt, Laurel Hill (R. H. Cambage, No. 871). "Messmate", Tumut (Forest Ranger Mecham). Gilmore, near Tumut (J. L. Boorman). "Tumut, at an elevation of about 3,500 feet." (C. C. Robertson and W. A. W. de Beuzeville, A. W. Howitt.) Talbingo Mountain, Tumut district. (A. W. Howitt, C. C. Robertson and W. A. W. de Beuzeville). The type.

"One of our best timbers for all purposes. I have seen blocks of this timber taken out of the ground after 30 years and they were still in good condition. (This applies to ground on which it grows.) We use it largely locally for telephone posts, rough building and especially T. and G. flooring and lining, and also for railway sleepers. It is locally a very large and tall tree, often 150-180 feet high. It is generally a very useful timber." Batlow. (W. A. W. de Beuzeville), also collected in the same district by A. W. Howitt, P. Murphy, W. Hutchison, F. W. Wakefield and W. H. Austin. The last is labelled *E. Australiana* by Mr. R. T. Baker. (Tumbarumba, "Tree with a fibrous matted bark." Bishop J. W. Dwyer No. 1418, F. W. Wakefield No. 9, J. Davis.) "Narrow-leaved Messmate." "Attains a height of over 100 feet and exceeds 4 feet in diameter. Is considered a fine timber and is largely used for fencing purposes. It is almost solely used at Kopsen's factory for pick-handles. It would make fine furniture, as it takes a good polish and looks exceedingly well when worked into chairs and tables. Found throughout the mountainous parts of the district. Grows equally well along sides of gullies and tops and sides of hills." Tumbarumba (H. A. Timms). Yarrangobilly (A. W. Howitt). "Messmate," Yarrangobilly saw-mills (W. W. Gillespie, E. Betche). Snowy River, near head of Murray (E. M. de Burgh). Mount Stromlo, and Condor Creek,

Federal Territory (C. Weston). Bondi Mountain and Devil's River, Tantawanglo Mountain (F. W. Wakefield).

The following are Western localities or its furthest point north of Gippsland, Victoria. Isabella River, Oberon to Burraga (F. W. Wakefield). Paupong (F.W.W.). "Very tall tree, with comparatively thin stem, 2-3 feet diameter, usually much less. Bark of Peppermint nature. Timber straight in grain. Not plentiful." Glengowan, Upper Meroo (J. L. Boorman and A. Murphy). Mullion Creek, near Orange (R. H. Cambage).

Affinities.—1. With *E. numerosa* Maiden. In botanical characters *E. numerosa* appears to be its closest affinity. In fact it may be described as a rough-barked form of *E. numerosa,* possessing a more durable timber, larger and more glaucous juvenile leaves, and sub-glaucous adult leaves, also glaucous, and more pointed buds. The umbels appear also to have fewer flowers in the head, and the pedicels are usually slightly shorter than those of *E. numerosa.*

2. With *E. radiata* Sieb. *E. Robertsoni* is a much larger and taller tree than *E. radiata,* possessing a better class of timber, and has larger and broader juvenile leaves, which are more glaucous than those of *E. radiata,* while the venation of the leaves is also different. On the other hand the buds are more pointed and even rostrate, and the peduncle and pedicels are usually longer in *E. Robertsoni* than in *E. radiata.*

8. E. MULTICAULIS n. sp.

Mallee parva erecta caulibus ramisque tenuibus; folia juvenilia sub-glauca, breviter petiolata, ovata vel elliptica; folia matura-excentia alternata, petiolata, lanceolata, vel falcato-lanceolata, subviridia, utrimque nitida; gemmæ globulares, pedicellatae; antheræ reniformes; capsulæ pyri-

formes vel urceolatæ-truncatæ, disco parvo, plano, 6-9 x 5-8 mm.

A small erect Mallee, with slender stems and branches; juvenile leaves sub-glaucous, shortly petiolate, ovate to elliptical; adult leaves alternate: petiolate, lanceolate to falcate-lanceolate, pale green, glossy on both surfaces; buds globular, pedicellate; anthers reniform; fruit pyriform to urceolate-truncate, disc small, flat, 6-9 x 5-8 mm.

A Mallee, 6-20 feet high, with numerous slender whip-stick, or clothes-prop-like stems ½-4 inches in diameter. Large-sized plants with a little rough, sub-fibrous bark on the lower part of stems, the upper portion smooth and usually purple-brown in colour. Branchlets sub-terete to quadrangular.

Juvenile leaves alternate, glaucous, shortly petiolate, ovate, elliptical to somewhat cordate, apiculate, thickish, usually lustreless, 4-10 cm. long, 3-9 cm. broad; venation scarcely prominent, the midrib slightly convex beneath, canaliculate on the upper surface of the lamina; lateral veins rather numerous, spreading at an angle of 20-40° with the midrib; intramarginal vein distant from the slightly revolute margin.

Intermediate leaves alternate, broadly-lanceolate to obliquely-lanceolate, dull, slightly glaucous, the lateral veins somewhat more distant than in the juvenile leaves, diverging at an angle of 40-50°, 7-12 cm. long, 4-7 cm. broad.

Adult leaves alternate, petiolate, obliquely-falcate to lanceolate, light green (not glaucous), drying a pale colour, glossy on both surfaces, coriaceous, copiously dotted with dark oil glands, the margins somewhat thickened, 6-12 cm. long, 1-3 cm. broad; venation somewhat longitudinal, the median nerve more or less obscure, especially on the lower surface; lateral veins radiating at an angle of

65-80° with the midrib and much closer together than in the intermediate leaves; intramarginal vein not far removed from the edge. Petiole semi-terete and usually twisted.

Inflorescence in axillary umbels, the peduncle compressed, up to 15 mm. long, supporting 5-12 pedicellate flowers. Buds drum-stick like, including the trigonous pedicels 5-8 mm. long. Calyx tube shaped like a wine-glass, about 2 mm. deep, operculum blunt, hemispherical, about 3 mm. in diameter, stamens white, very numerous, attached to the inner edge of the calyx-tube or staminal ring in two or three closely-packed irregular rows, only the inner ones antheriferous and shorter than the outer ones. Anthers very small, reniform with a large globular semiterminal gland in front. Style slender, subulate, not exceeding the top of the calyx-tube.

Fruit pyriform-truncate, to slightly urceolate, flat-topped or slightly convex, the small capsular disc growing well out towards the centre of the capsule and extending over the very small enclosed valves, or the latter rarely exsert, usually three celled, 6-9 mm. long, 5-8 mm. in diameter.

Range.—So far it appears to be confined to the Lower Hawkesbury, between Broken Bay and Gosford, New South Wales, and grows mainly on poor, shallow, moist sandstone slopes with a southerly or south-east aspect.

Head of the left arm of Patonga Creek, about 1½ miles beyond tidal water; Sugar Loaf, over the Woy Woy tunnel; Kariong Trig., 807 feet above sea level, and about 7 miles air-line from Broken Bay. The type locality. It extends from Kariong in a southerly direction for about 1½ miles on the south-east slope of two prominent ridges which are very little lower than the Trig., and in several places it forms pure stands one to several acres in extent. In one spot on the southern end of Kariong it is intermixed with *E. virgata,* but as a rule it prefers the slightly

better and drier soil than the latter species, and it has not been observed to grow on the rocky precipitous slopes like *E. virgata* does in this locality. (W. F. Blakely, D. W. C. Shiress and H. Bott.) Head of Kendall's Glen, Gosford (W.F.B., and D.W.C. Shiress.)

Affinities.—1. With E. *Sieberiana* F.v.M. *E. multicaulis* might be called a Mallee form of *E. Sieberiana*, as it somewhat resembles it in botanical characters, but it never seems to grow into a tree like *E. Sieberiana*. Sometimes *E. Sieberiana* sends out several small saplings from the rootstock, but they resemble the typical form in every way except in manner of growth. But they are very dissimilar from *E. multicaulis* in the nature of the bark, which is thicker, harder, and more rugged on the lower portion of the trunks, while the bark of the upper is smooth, glaucous or pruinose, in contradistinction to the short, brittle mealy-fibrous bark on the base of the stems of *E. multicaulis*, and the smooth, reddish or purple-brown bark on the upper portion. The juvenile leaves of *E. multicaulis* are smaller, thinner and less glaucous than those of *E. Sieberiana*. It is common to find the juvenile leaves of the latter species 18 cm. long, and 10 cm. in diameter. The fruits of *E. multicaulis* are also slightly smaller than, and somewhat differently shaped to, those of *E. Sieberiana*.

2. With *E. Consideniana* F.v.M. This species is usually a medium-sized tree, and so far as I am aware it has not been known to form a Mallee-like growth like *E. multicaulis*. The bark of the two species is also dissimilar in texture, and there is a marked difference in the juvenile leaves and in the sculpture of the fruit of both species.

9. E. Bleeseri n. sp.

Bloodwood, arbor mediocris; cortex caulis ramorumque glaber; ramuli compressi, mox teretes; folia matura alter-

nata, petiolata, angusti lanceolata, acuminata; inflorescentia formans paniculam terminalem magnam, corymbosam; gemmae ovoideae, glabrae; antherae versatiles; capsulae cylindraceo-urceolatae, 1.5-2.5 x 1-1.2 cm.

A moderately smooth, white-barked Bloodwood, up to 50 feet high. Bark at base thin-flaky, semipersistent, whitish to pale reddish-brown. Branches smooth; the old bark, which is of a reddish-brown colour, decorticates annually in small, thin flakes, leaving the branches and portion of the stem smooth and white. Branchlets at first compressed, sulcate, but soon becoming terete, usually of a reddish-brown colour.

Juvenile leaves very variable, the lower ones alternate, petiolate, orbicular to ovate, apiculate, scabrous and loosely pilose, 3.5-7 cm. long, 3-5 cm. broad. Venation somewhat transverse, almost obscure, except the intramarginal vein, which is conspicuous at the base, and distant from the margin. Internodes compressed, sulcate, densely pilose with reddish hairs; young tips infested with purple-brown hairs. Upper juvenile leaves opposite for 2 or 3 pairs, then alternate, oblong to broadly lanceolate, petiolate, very scabrous, almost peltate, or an odd one peltate, very dull, with a few scattered hairs or seta on the margin and midrib, 6-10 cm. x 2.5-7 cm., more or less aromatic when crushed. Venation somewhat transverse, moderately distinct, diverging at an angle of 65-75° with the midrib. Internodes compressed or terete, pilose.

Intermediate leaves opposite for 2 or 3 pairs, then alternate, petiolate, coriaceous, smooth and shining, slightly pale on the under surface, broadly oblong-lanceolate, [illegible]e, 8-18 cm. long, up to 6.5 cm. broad. Venation transverse or nearly so, very fine, almost obscure, the median nerve rather broad, convex beneath, channelled

above; lateral veins spreading at an angle of 75-80° with the midrib; intramarginal vein concealed by the thickened nerve-like margin.

Adult leaves alternate, petiolate, narrow-lanceolate to obliquely-lanceolate, acuminate, thin, light-green, glossy on both sides, 10-16 x 1-2 cm. Venation almost transverse, very fine, the median nerve reddish, compressed or scarcely raised above the lamina; lateral veins very numerous, radiating at an angle of 75-80° with the midrib; intramarginal vein indistinguishable from the thin nerve-like margin. Petiole slender, convex beneath, channelled above, 10-15 mm. long, 1-1½ mm. in diameter.

Inflorescence forming large terminal compound umbels or corymbose panicles; partial umbels 3-6 flowered; flowers on slender, slightly dilated pedicels 15-25 mm. long. Buds somewhat ovoid, slightly acute, tapering into the pedicels, smooth, pale-coloured or reddish, straight or curved at the base like the bowl of a tobacco pipe, 10-13 x 6-8 mm. Calyx-tube obconic, moderately thick, 7 mm. long; operculum broadly conical, slightly rugose at the top, shorter than the calyx-tube. Filaments white; anthers versatile, rather large, the cells longitudinal with a large oval dorsal gland.

Fruit obliquely cylindroid-urceolate, to oblong-urceolate, 1.5-2.5 cm. long, 1-1.2 cm. in diameter; the capsular disc fairly well developed, internally deeply oblique, the orifice considerably smaller than the expanded top of the capsule; valves deeply sunk, sometimes much lower than the base of the capsular disc.

Timber a very pale pink when fresh, with a moderately long straight grain, strong and tough, of medium weight.

Illustrations.—It is figured in the Critical Revision of the Genus Eucalyptus, Part lxix, Plate 280, figs. 4-5.

Synonym.—*E. terminalis* F.v.M. var. *E. longipedata* Maiden and Blakely Crit. Rev. Part lxix, p. 407.

Range.—In the present state of our knowledge, it seems to be confined to Port Darwin, Northern Territory, and was first collected by Schultz about 1880, who forwarded specimen to the late Baron Von Mueller for identification.

It apparently had escaped the observation of many collectors who visited Darwin since the above date, until it was rediscovered by Mr. C. E. F. Allen, in March, 1917, who submitted a flowering specimen to the late Mr. J. H. Maiden, who asked Mr. Allen to supplement his specimen with ampler material, but the request was left in abeyance.

In February, 1927, Mr. F. A. K. Bleeser, of Darwin, pointed out the tree to Mr. D. W. C. Shiress, who brought back specimens which enabled me to establish its identity. Mr. Bleeser has also sent specimens, together with a sample of the timber, and field notes concerning it.

I therefore name the species in honour of Mr. F. A. K. Bleeser, Assistant Postmaster, Port Darwin, who for upwards of 38 years has taken a very keen interest in the flora and fauna of the Northern Territory.

Affinities.—1. With *E. terminalis* F.v.M. The buds and fruits of both species are somewhat similar in shape and size, but the long slender pedicel of either character of *E. Bleeseri* readily differentiates it from *E. terminalis;* the operculum is also longer and more pointed in the former. In the field the former may be distinguished from the latter by its moderately smooth white bark in contradistinction to the rough bark of *E. terminalis.*

2. With *E. dichromophloia* F.v.M. The buds and fruits of *E. Bleeseri* are larger than those of *E. dichromophloia,* while the bark of the former is smooth, not rough like that of the latter.

THE ESSENTIAL OIL OF *EUCALYPTUS BAKERI* (MAIDEN).

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Acting Curator and Economic Chemist, Technological Museum, Sydney.

(Read before the Royal Society of New South Wales, July 6, 1927.)

This very interesting species of Eucalyptus was described by the late J. H. Maiden, F.R.S., in the Journal of the Royal Society of New South Wales, Volume 47 (1913), page 87. It is also referred to again in his "Critical revision of the Genus Eucalyptus", vol. 5, page 123.

It was described as a large shrub or pendulous willow-like tree about 30 to 50 feet high, known vernacularly as "the Mallee Box", with a range from Northern New South Wales to Central Queensland. The leaves are very narrow. The author was unacquainted with the species until Dr. T. L. Bancroft, of Eidsvold, Queensland, brought it under the notice of the Technological Museum and suggested the investigation of its essential oil on account of the pleasant aroma detected on crushing the leaves. Curiously enough, Mr. J. H. Maiden, when describing the species, stated "this is a specially interesting species, rich in oil". If available in sufficient quantity the oil should be of economic value to Queensland, as this State, so far as we know, is poorly provided with Eucalyptus oils rich in cineol available in commercial yield.

Dr. Bancroft has informed me that the trees at Eidsvold attain a height of 40 to 50 feet with a stem of a foot to 18 inches in diameter, and much branched. Most of the material forwarded by him for this investigation was obtained from the "sucker" growth that springs from the butts after bush fires.

The Essential Oils.

Three consignments of leaves and terminal branchlets were kindly provided by Dr. T. L. Bancroft, Eidsvold, Queensland, whilst a check collection of material obtained from Inverell, New South Wales, was kindly furnished by the Forestry Commission of New South Wales, through the District Forester at Inverell.

The oils, obtained in a yield of 2% on air-dried material and 1% on freshly-cut leaves, in every case were of a bright reddish-yellow colour, resembling in all general physical characters the well-known commercial oils obtained from the "Mallees", *E. polybractea* and *E. cneorifolia*, so much so that its separation therefrom would be most difficult. The principal constituents identified, cineol (70-77%), cymene, the aromatic aldehydes (cuminal, phellandral, cryptal) are identical with those present in the species mentioned. Two other constituents, quite new to the Eucalypts, were also identified, viz., phloracetophenone-dimethyl ether, and the esters (isobutyric, isovaleric and formic) of the alcohols corresponding to the aromatic aldehydes, cuminal and phellandral. Other minor constituents such as Australol, d-a-pinene, and a sesquiterpene alcohol were also found. A remarkable feature in connection with the oil was the isolation of phloracetophenone-dimethyl ether, a solid phenol ether of melting point 82-83° separated from the first consignment received from Dr. Bancroft on the 26th October, 1925. As this constituent has not previously been detected in Eucalyptus Oils, although known to the writer to be present in quantity in some oils separated from plants of the N.O. Rutaceae shortly to be described, it was decided to secure additional consignments of leaves with a view to confirming its presence in a general way. Unfortunately it was not found in any of the other consignments, although evidence of its

EUCALYPTUS BAKERI.

Date.	Locality.	Weight of Leaves.	%age Yield of Oil.	$d\frac{15}{15}$	α^{20}_{D}	n^{20}_{D}	Solubility in 70% Alcohol (by weight)	Ester No. 1½ hrs. hot.	Ester No. after Acetylation.	Congealing Point.	Cineol (Phos. acid method)
26/10/1925	Dr. T. L. Bancroft, Eidsvold, Q.	292 lbs.	2.2%	0.9335	-0.7°	1.4633	1 vol.	20.5	38.5	-9°	73%
27/5/1926	District Forester, Inverell, N.S.W.	100 lbs.	1.12%	0.9257	+1°	1.4641	1 vol.	18.6	39.3	-13°	70/72%
5/8/1926	Dr. T. L. Bancroft, Eidsvold, Q.	420 lbs.	2.05%	0.9296	-0.7°	1.4629	1 vol.	20.1	36.9	-8½°	75/76%
28/1/1927	do. do.	112 lbs.	1.81%	0.9260	-1.2°	1.4642	1 vol.	19.6	45.7	-14°	70%

presence through the characteristic colour reaction with ferric chloride was obtained, the principal phenol in every other instance being identified as Australol (p-isopropyl phenol).

Experimental.

A total of 924-lbs. weight of leaves and terminal branchlets, cut as for commercial purposes, yielded on distillation with steam, crude oils, possessing the chemical and physical characters, as shown in table:—

On distillation at 757 m.m., the crude oils, in practically every instance, yielded 83 to 85% distilling at 174-183°, or 90% at 61-66° at 10 m.m. For the examination of the principal components it was found best to steam distil one litre portions of the crude oils, leaving a residue of about 14 to 18% in the flask.

Each consignment was similarly treated, but only the examination of the steam distilled portion for cineol and terpenes of the 5/8/1926 lot will be recorded.

This steam distillate possessed the following constants:—

$$d\frac{15}{15},\ 0.9263,\ \alpha^{20}_{D},\ \pm 0,\ n^{20}_{D},\ 1.4611.$$

It was washed with sodium hydroxide and sodium bisulphite solutions respectively, and then distilled several times over metallic sodium. Repeated efforts were made to concentrate the cineol by freezing, etc., but it was found impossible to obtain it free from cymene. Treatment with 50% resorcin solution was no more successful, and oxidation was not practicable. It was found impossible to identify by chemical means the principal terpene or hydrocarbon accompanying the cineol. The particular fraction was found to distil at 172-174° (u.c.) at 768 m.m. and to have

$d\frac{15}{15}$, 0.9241, α^{20}_{D}, + 0.25°, n^{20}_{D}, 1,4600. Congealing point, − 3.5°

Determination of Cymene.—The presence of this hydrocarbon was definitely proved by preparing a 1% solution of the fraction in 7½% rosin soap solution and determining the Rideal-Walker co-efficient against *B. typhosus*. Mr. R. Grant found the figure 8.5. It was shown by the writer in conjunction with Mr. R. Grant (this Journal, Vol. LIX, 1925, pages 347/348) that pure cymene with co-efficient of 8, if present in admixture with terpenes, etc., raises the co-efficient of the latter, which possesses comparatively low values, out of all proportion to the percentage it bears to the other components. In this case it has raised the co-efficient of the cineol from 3.5 to 8.5, although the cineol content of the mixture approximated 90%. It is very satisfactory evidence of the presence of cymene.

Determination of d-a-Pinene.—The Inverell sample of oil possessed a slight dextro-rotation, and it was availed of in order to trace the component from which this particular optical activity arises in the various cineol fractions. Moreover, it was the only sample of crude oil possessing a dextro-rotation, the others being laevo-rotatory. 100 c.c. of the Inverell sample on distillation at 10 m.m. yielded 20% distilling below 63° possessing the following characters:—

$$d\frac{15}{15},\ 0.9184,\ \alpha_D^{20},\ +\ 3^\circ,\ n_D^{20},\ 1.4605.$$

On treatment with dilute potassium permanganate solution at room temperature and separation of the unchanged cineol and cymene it was possible to isolate a very small quantity of pinonic acid from the aqueous solution after removal of the manganese sludge. This acid was converted to the semicarbazone, which melted sharply at 207°, thus confirming the presence of d-a-pinene, as suspected.

Examination of residue left in flask after steam distillation.

Determination of Phenols.—The residue remaining in the flask from the 26/10/1925 consignment was treated

with 8% sodium hydroxide solution, when on washing with ether and subsequent acidification with dilute sulphuric acid solution, 16 grams of a crude solid phenol were obtained.

On recrystallisation from xylene (methyl alcohol was subsequently found to be a better solvent) it melted at 82-83°. A combustion and molecular weight determination showed it to possess the formula $C_{10}H_{12}O_4$ and to be identical with phloracetophenone-dimethyl ether, a white crystalline solid. A mixed melting point determination made with the same substance separated from various species of *Geijera,* as yet unpublished, showed no depression. The striking violet red colouration which this body gives with Ferric Chloride in alcoholic solution was likewise obtained. Its identity was confirmed by the preparation of the Monobromo-derivative, which melted at 188-189°. A mixed melting point determination made with the derivative prepared from phloracetophenone-dimethyl ether from the source just mentioned showed no depression. This is the first record of the occurrence of this substance in Eucalyptus Oils and adds another to the long list of constituents which have been isolated from this source.

A very remarkable feature of the isolation of this phenol ether, which was present to the extent of 1.8%, was the failure to obtain it again, although a number of consignments of leaves were specially secured for that purpose.

The phenolic portions of the other consignments did not solidify (a feature of the 26/10/1925 lot), but were found to consist mainly of Australol (p-isopropyl phenol), through its identification by means of the Benzoyl compound of melting point 73-74°. A quantity of 8 c.c. [illegible] phenol separated ex 5/8/1926 lot was distilled at

·3 m.m., when the greater portion came over at 100-115°. This distillate gave a purplish colouration with ferric chloride in alcoholic solution similar to that given with phloracetophenone-dimethyl ether. Apparently this body is present in variable quantity in most of the "Mallee" Oils and the author has apparently been singularly fortunate in observing its occurrence in quantity and practically free from admixture with other phenols in this particular lot of oil, 26/10/1925.

Australol does not give a colour reaction with ferric chloride in alcoholic solution. On placing the distillate referred to in a freezing mixture and seeding it, solidification took place, and although obtained in a condition of purity in comparatively poor yield, the crystals when separated and re-crystallised from Xylene, melted at 62-63°. A mixed melting point determination using crystals of Australol from the Oil of *E. cneorifolia* showed no depression.

Determination of Aromatic Aldehydes.—The residual oil left after treatment with sodium hydroxide solution was shaken with 35% sodium bisulphite solution and the solid bisulphite compound separated by filtration. It was washed with ether-alcohol, dried on a porous plate and the aldehydes liberated by means of sodium carbonate in a current of steam. Two such preparations of cuminic aldehyde with a small amount of phellandral were thus obtained:—

	26/10/1925.	5/8/1926.
Volume	4 c.c. (ex 1000 c.c. crude oil)	8 c.c. (ex 2035 c.c. crude oil)
$d\frac{15}{15}$	0.979	0.978
α_D^{20}	$-12°$	$-9.2°$
n_D^{20}	1.5211	1.5253

The quantities available were too small for the phellandral to be separated therefrom by the method of the author (J.C.S. Vol. 121 (1922), page 266). Both samples yielded the semicarbazone typical of Cuminal, melting point 210-211°.

The filtrate from the crude Cuminal bisulphite compound, after washing with ether, was decomposed with sodium hydroxide solution and the liberated aldehyde collected. Two such preparations possessed the following characters.

	26/10/1925.	5/8/1926.
Volume	6½ c.c.	18 c.c.
d_{15}^{15}	0.956	.
a_D^{20}	- 44°	
n_D^{20}	1.4909	...

Both samples were further purified by treatment at room temperature with 35% sodium sulphite solution, which combines only the cryptal, the uncombined aldehyde being mainly phellandral. Preparations of purified cryptal separated from the above mentioned mixed aldehydes gave the following results on examination:—

	26/10/1925	5/8/1926.
B.pt. 10 mm.	99/100°	99/100°
d_{15}^{15}	0.930	0.950
a_D^{20}	- 44°	- 55°
n_D^{20}	1.4811	1.4852

The preparation of the semicarbazone melting at 183° confirmed their identity with cryptal.

The aldehyde which did not react with neutral sulphite solution was obtained to the extent of 6 c.c. only from 5/8/1926 lot. It distilled at 105-107° at 7 m.m., and the distillate possessed the following constants:—

$$d_{15}^{15}\ 0.957,\ a_D^{20}\ -37°,\ n_D^{20}\ 1.4976.$$

The characteristic oxime melting at 87-88° was readily prepared and afforded confirmation of its identity with phellandral.

Although these three aldehydes, cuminal, phellandral and cryptal, were not individually obtained in a condition of great purity, yet their identification was readily accomplished, and once again it has been shown that all three occur together in Eucalyptus Oils of this type. (J.C.S. Vol. 121 (1922), page 266.)

Other Constituents.—The oil remaining after removal of phenolic and aldehydic constituents was then saponified with alcoholic potassium hydroxide solution to decompose the esters present and then distilled at 10 m.m.:—

130 c.c. of such oil ex 5/8/1926 yielded the following fractions on distillation:—

Fraction.	Volume.	$d\frac{15}{15}$	α_D^{20}	n_D^{20}
Below 75° at 10 m.m.	80 c.c.	0.9252	+0.55°	1.4612
75 - 100°	8 c.c.	0.9407	+6 1°	1.4776
100 - 135°	25 c.c.	0.9568	+6 4°	1.4960

The first named fraction consisted largely of Cineol and Cymene.

Determination of Aromatic Alcohols and Sesquiterpene Alcohol.—The examination of the higher boiling fractions showed the presence of aromatic alcohols as well as a dextro-rotatory sesquiterpene alcohol, the latter, of course, being at present unidentified. On heating, however, a portion of the third fraction, with phthalic anhydride for 4 hours at 140°, a phthalate was obtained, which on decomposition with sodium hydroxide in a current of steam yielded a colourless liquid possessing the following physical characters:—

$$d\frac{15}{15}\ 0.9587,\ \alpha_D^{20}\ -2.4°,\ n_D^{20}\ 1.4990.$$

It did not yield a phenylurethane or naphthylurethane on treatment with phenylisocyanate or naphthylisocyanate respectively, but on oxidation with Beckmann's Chromic acid solution a good yield of cuminic acid of melting point 115-116° resulted. The production of this acid pointed to the alcohol being identical with Cuminol or Cuminic Alcohol, but it should show no optical activity and doubtless the slight laevo-rotation is due to the presence of another alcohol corresponding to the aldehyde Phellandral. Confirmation was afforded by oxidising under similar conditions a small quantity of Cuminic Aldehyde containing some phellandral, isolated from the Oil of *Eucalyptus cneorifolia* in 1921, possessing the following physical characters:—

B.pt. 10 m.m., 110°, $d\frac{15}{15}$, 0.9802, α_D^{20} $-7.6°$, n_D^{20} 1.5281.

This composite aldehyde yielded as principal product cuminic acid of melting point 115-116°. A mixed melting point of both acids showed no depression.

There seems to be no doubt on the evidence adduced, that the alcohols present represent cuminol with some phellandrol, constituents not previously shown to be present in Eucalyptus or other essential oils. The author believes that these alcohols are present in the higher boiling portion of such oils as *E. polybractea* and *E. cneorifolia.*

Determination of Free and Combined Acids.—During the purification of the crude phenolic portion removed from the oil with sodium hydroxide solution, it was dissolved in ether and washed with sodium bicarbonate solution. By this means a small quantity of free acid was removed by the latter and obtained by acidulation with dilute sulphuric acid and steam distillation. The silver salt was prepared and on ignition 0.2025 gram yielded 0.1265 gram silver = 62.47%. The silver salt

readily turned black and qualitative analysis revealed the presence of isobutyric and formic acids.

The saponification liquors from the treatment of the high boiling portion of the oil with alcoholic potash solution were worked up and the combined volatile acids liberated with dilute sulphuric acid and subsequent steam distillation. The ammonium salts were first prepared and converted to the silver salts, which gave the following results on ignition:—

26/10/1925.

1st fraction—0.3894 gram silver salt gave 0.2408 gr. silver
= 61.84% Ag.

2nd fraction—0.2528 grams silver salt gave 0.1584 gr. as.
= 62.66% Ag.

5/8/1926.

1st fraction—0.3904 gram silver salt gave 0.2422 gr. as.
= 61.79% Ag.

2nd fraction—0.7801 gram silver salt gave 0.4836 gr. as.
= 62.25% Ag.

3rd fraction—0.2850 gram silver salt gave 0.1710 gr. as.
= 61.01% Ag.

A small quantity of an oily acid was present which was not definitely identified. The qualitative analysis revealed the presence of isobutyric, isovaleric, and formic acids.

In conclusion, my thanks are due to Dr. T. L. Bancroft, Eidsvold, Queensland, for his enthusiastic and practical interest in these investigations in kindly forwarding at his own expense the various consignments of leaves; to the Forestry Commission of New South Wales for the lot from Inverell; and to Mr. F. R. Morrison, A.A.C.I., F.C.S., Assistant Economic Chemist, for valuable help in the examination of the crude oils.

RIGOROUS ANALYSIS OF THE PHENOMENA OF MULTIPLE BIRTHS.

By SIR GEORGE H. KNIBBS, C.M.G., M.I.Inst.deStat., Hon. F.S.S., Hon. M.Amer.S.A., Hon. M.Stat.S. Hungary, etc.

(With two text figures.)

(Read before the Royal Society of New South Wales, August 3, 1927.)

Synopsis: 1. Principles of analysis. 2. Secular fluctuations in the frequency of multiple births. 3a. Masculinity of multiple births. 3b. Further elements in the phenomena of multiple births. 4. Data for the study of the above questions. 5. Masculinity of births according to the age of the mother. 6. Law of frequency according to age in the production of twins. 7. Fluctuation with time of frequency according to age. 8. Sex-distribution in the case of twins. 9. Fluctuation of masculinity, according to age of mothers. 10. Relation between the proportion of uniovular cases, and the relative frequency of the occurrence of twins. 11. Ratio of uniovular cases of twins to cases of maternity. 12. The frequency of triplets in relation to maternity. 13. Sex-distribution of triplets. 14. Quadruplets. 15. Conclusions.

1. *Principles of analysis.*—The rigorous analysis of the phenomena of multiple-births takes the most simple form, if such births are directly referred to the actual number of cases of maternity, instead of being related to the numbers of women at risk. Thus C denoting the number of cases of actual confinements—mothers giving birth to (say living) children, and T the number of cases of twins, S the number of cases of triplets, Q cases of quadruplets, we may denote the ratios as follows:—$t = T/C$; $s = S/C$; $q = Q/C$; etc. To denote the age, last birthday, of the mothers we shall use x. Then, b denoting the rate for single births, viz. B/C, the number born, viz. B′, is

(1) .... $B' = C\,(b + 2t + 3s + 4q +$ etc.)

In reviewing the data it has to be remembered that many females do not state their ages correctly, either owing to lapses of memory or for other reasons; consequently the rates found are really ratios for persons not actually of the indicated age, but *declared* to be of that age. We are never quite certain that the values B, C, b, t, s, q, etc., correspond to the actual age x to which they are assigned. Owing to this all values, whether absolute or merely ratios, are to be regarded as subject not only to the limitation of departing from any ideal law, owing to the paucity of the numbers, but also owing to mis-statement of the facts. One must therefore treat the data as only approximately correct, and as pointing out the ideal laws of the phenomena, rather than as specifically furnishing their numerical expression.

2. *Secular fluctuations in the frequency of multiple births.*—Since multiple births are relatively rare, the first question is "whether they tend to be a constant proportion in the cases of maternity in which they appear?" Since they are, as it will later be seen, a function of the age of the mother, the constitution according to age of the mothers bearing children must not appreciably differ, if the *crude ratios* are to be considered as comparable, without material correction. As they do not differ greatly, we shall indicate in a table the crude fluctuations of the rates of births, such rates being referred to the number of cases of maternity occurring in the years under review.[1]

1. The number of cases of maternity are found either by deducting from the number of "births registered" the number of cases of twins, plus twice the number of cases of triplets, plus three times the number of quadruplets; or by adding to the number of mothers of single births, the number of mothers of twins, of triplets, etc.

Table I. Number of maternities, and the twins, triplets, and quadruplets resulting therefrom, in Australia, from 1890 to 1925; and rates.

Year	Mothers	Twins	Trip.	Quad.	Rate (a)	Year	Mothers	Twins	Trip.	Quad.	Rate (a)
1890	75779	751	4	0	991	1907	110849	1029	14	0	932
1	77157	800	3	0	1037	8	111556	1059	6*	0	949
2	77220	630	11	0	816	9	114063	1128	14	0	989
3	76127	746	9	1	980						
4	72521	674	7	0	929	1910	116798	1176	18	0	1007
						1	122193	1222	14	0	1000
5	71734	722	9	2	1007	2	133076	1334	16	0	1002
6	68065	611	4	0	898	3	135712	1361	8*	0	1003
7	67813	735	3	1	1084	4	137977	1395	11	0	1010
8	65733	653	4	0	993						
9	66737	722	5	0	1082	5	134861	1407	10	0	1033
						6	131414	1371	12	0	1033
1900	67198	717	5	0	1067	7	129947	1477	17	1	1137
1	68146	717	10	0	1052	8	125731	1362	8*	0	1083
2	67574	704	9	0	1042	9	122283	1311	15	1	1072
3	64880	641	7	0	988						
4	67702	716	6	0	1057	1920	136396	1505	16	0	1103
						1	136192	1453	12	0	1067
5	68843	747	9	0	1085	2	137500	1432	12	0	1042
6	71027	759	3	0	1069	3	135232	1394	6*	0	1031
7	72815	729	11	0	1001	4	134932	1337	12	0	991
8	72825	720	5*	0	989						
9	74533	773	10	0	1037	5	135812	1458	11	0	1074
1910	76001	802	9	0	1055						
1	79727	818	9	0	1026						

(a) The rates for twins are per 100,000.

The results on the left-hand side of the table are for New South Wales and Victoria taken together: those on the right-hand side are for the whole of Australia. The years 1907-1911 are common to both, the average for the former being 1021.6 and for the latter 975.4, or 46.2 less.

The ratios of the number of twins to the number of maternities exhibit two periods of rapid increase, viz. from 1892 to 1899, and from 1909 to 1919. This is readily seen from Table II, which gives the 5-year means of the yearly rates, as follow:—

* The first value for 1909, and all the values in the first three columns are means of the rates for New South Wales and Victoria taken together.

Table II: Five-year means of the rates of the appearance of twins.

Year	Means	Year	Means	Year	Means
1892	951	1898	1025	1904	1048
3	954	9	1056	5	1040
4	926	1900	1047	6	1040
5	980	1	1046	7	1036
6	982	2	1041	8	1030
7	1013	3	1045	9	1022*
1909†	975	1915	1043	1921	1063
10	989	16	1058	22	1047
11	1000	17	1072	23	1041
12	1004	18	1086	24	1032‡
13	1010	19	1092	25	1074
14	1016	20	1073		

The reasons for the increases, and changes in the rate of frequency in the appearance of twins in cases of maternity, are not known and call for further study.

The frequency of triplets is rare, relatively, and the absolute numbers are so small that comparisons for single years have practically no value. It may be noted as a curious fact that the numbers occurring in the years 1908, 1913, 1918, and 1923, are conspicuously small, averaging, for the whole of Australia for those years, only seven each year, and never differing more than one from this average. This remarkable periodicity of 5 years, however, does not manifest itself earlier than this.

Quadruplets are of course still more rare, and in the whole period covered, viz. 36 years, number only six cases, very irregularly distributed.

No cases of quintuplets have been recorded during the period under review. They have been reported in the former German Empire, and also sextuplets.

* The first value for 1909, and all the values in the upper three columns are means of the rates for New South Wales and Victoria taken together. † The second value for 1909, and all the values in the lower three columns of rates are means for the whole of Australia. ‡ The value for 1924 is the mean of three years, and that for 1925 is the value for that year, itself, only.

Taking the data in their totality, we get for 1,570,157 cases of maternity in New South Wales and Victoria between 1890 and 1911 inclusive, and for 2,442,024 cases in Australia between 1907 and 1925 inclusive, the following rates for the appearance of twins, triplets, and quadruplets:—

Table III. Frequency of Multiple Births.

	Maternities.	Twins.	Triplets.	Quadruplets.
Victoria and New South Wales	1,000,000	10,054	96.8	2.55
Whole of Australia	1,000,000	10,324	93.0	0.82
German Empire, 1872 to 1880. .	1,000,000	12,856	124.0	1.33
Vic. & N.S.W. & Aust., 1890-1925	1,000,000	10,218	94.5	1.50

These results show that the frequency of twins passes through a fairly wide range; thus in Australia, even for these lengthy periods, they range from 0.010054 to 0.010324, while in Germany they rose to 0.012856. H. Prinzing, in his "Handbuch der medizinischen Statistik", gives results ranging between 0.0087 for Spain to 0.0147 for Finland. Even in any one country they may range through wide values. For example, in Italy for 1892-1899 they ranged between 0.0080 for Basilicata to 0.0148 for Venice. Having regard to facts such as these it would appear unsound to attempt to give any indication that there is a *trend* in the frequency. It is worthy of noting that the German rate of triplets is 0.906 per cent. of that for twins, while the Australian rate, 1890-1925, is 0.924 per cent.

3a. *Masculinity of multiple births.*—The degree of masculinity in the cases of multiple births must of course be compared with that of births generally, in order that its significance shall clearly appear. Defining masculinity as the ratio of the difference of the males and females divided by their sum, that is $(m-f)/(m+f)$, the results for Australia for the 18 years, 1908 to 1925 inclusive, per

10,000 (that is the ratio multiplied by that number) is as shown in the following table:—

Table IV. Fluctuation of Masculinities in cases of first-births and all births, in Australia, 1908 to 1925, inclusive.

Yearly results.						Five-year means.					
Year	1st	All	Year	1st	All	Year	1st	All	Year	1st	All
1908	190	240	1917	273	292	1910	257	251	1917	308	270
9	247	254	8	260	253	1	269	250	8	300	282
1910	353	309	9	280	292	2	268	246	9	287	285
1	293	231	1920	282	301	3	261	232	1920	288	280
2	208	222	1	338	285	4	284	240	1	289	281
3	249	232	2	280	267	5	298	254	2	280	262
4	241	234	3	264	259	6	301	258	3	278	250
5	319	239	4	236	198	The masculinities are per 10,000.					
6	410	273	5	272	242	5-year means.			5-year means.		

The 5-year means are assigned to the middle year of the group of five.

The above results show that, *even for large numbers of births, the masculinity varies greatly,* the yearly results of course being more divergent than the 5-yearly means, though even the latter range between 257 and 308 for first-births, and 240 and 285 for all births. There is no definite indication of a secular trend, but it is important to note that the masculinity for first-births and "all births" is always *positive*; the means of the yearly values indicate that with 10,000 first-births there will on the average be 277 more males than females, and with 10,000 "all births" 257 more. The significance of this will appear when we come to consider the masculinity of multiple births.

Table V. Masculinity (over all) of twins and triplets, Australia, 1916-1925.

Year	1916	17	18	19	1920	21	22	23	24	1925	1916-25
Twins	1371	1477	1362	1311	1505	1453	1432	1394	1387	1458	14100
Masc.	+357	—54	+184	+53	+279	+158	—21	+86	+419	+219	+168.8
										Average	168.0.
Trip.	12	17	8	15	16	12	12	6	12	11	121
Masc.	—389	+120	+88	—378	+208	+389	—111	+111	—222	+91	—19.3
										Average	—9.8.

The masculinities for the twins are per 10,000; those for triplets are per 1,000; and must be multiplied by 10, if they are to be compared with those for twins.

The above table shows that the masculinity for twins and that for triplets is very variable: for the former it is generally positive, being negative only for years 1917 and 1922; for the latter the numbers are so small that the results cannot be regarded as accurately disclosing the general tendency, or law of the phenomena. It is important to note, however, that the mean of the yearly values of the masculinities, from 1916 to 1925, for all births was 266.2; while in the case of twins it was only 168.0, that is, 0.63 of the former. We cannot therefore properly assume, in any theory of the occurrence of twins, that the relative frequency of the production of males and females is independent of the fact of the births being single or multiple births.

3b. *Further elements in the phenomena of multiple births.*—What has just been stated suggests that, since masculinity in the case of twins differs from that of births generally, applications of the theory of chance thereto, need to be made with caution. The further study involves the following questions among others, viz.:—

(a) Is the frequency of the occurrence of twins a function of the age of the mother?

(b) Does the masculinity of multiple births vary with the age of the mother, and is it a definite function of her age?

(c) Is the relative frequency of the production of multiple births from a less number of ova than there are births, a function of the age of the mother?

4. *The data for the study of the above questions.*—The available data for the analysis of multiple births having regard to the ages of the mothers are for the years 1920 to 1925 only, and are to be found in the Australian Demography Bulletins, published by the Commonwealth

Statistician.[1] From these the following table has been compiled. The six years' results are hardly sufficient for the questions to be well answered, but they are sufficient to furnish results of considerable importance from the standpoint of the laws of human reproduction. Twenty years' data will yield results of higher precision.

Table VI. Cases of maternity, masculinities of single births, cases of twins, their masculinity, ratio of cases of twins to the number of mothers, and the sex distribution of the twins, Australia, 1920 to 1925.

(i) Age.	(ii) Mothers.	(iii) MSB.	(iv) Twins.	(v) Calc.	(vi) T.M.	(vii) Calc.	(viii) M.T.
10	0	–	0	0	0	0	–
11	0	–	0	0	0	58	–
12	6	0	0	0	0	117	–
13	26	1200	1	0	3846	176	–
14	171	820	1	0	585	234	–
15	513	—39	3	2	585	293	–
16	2106	353	11	7	522	351	—66$_7$
17	5715	207	22	23	385	410	+ 3$_7$
18	11735	346	54	55	460	·468	—27$_7$
19	18809	264	121	99	643	526	—21$_7$
20	25065	293	134	147	535	585	—17$_8$
21	32201	269	205	207	637	644	—13$_8$
22	38050	250	266	267	699	702	+ 7$_8$
23	43167	309	337	328	781	760	+13$_8$
24	46157	316	349	378	756	819	+18$_8$
25	47395	268	437	416	922	878	+25$_8$
26	48204	250	443	452	919	936	+14$_8$
27	47295	301	469	470	971	994	+23$_8$
28	47104	262	466	496	989	1053	+21$_8$
29	45228	272	521	503	1152	1112	+57$_8$
30	45920	195	545	537	1187	1170	+48$_8$
31	38060	263	458	468	1203	1228	+68$_8$
32	38674	256	486	498	1257	1287	+38$_8$
33	34388	269	483	463	1405	1346	+39$_8$
34	32063	315	456	450	1422	1404	+17$_8$
35	28975	224	419	424	1446	1462	+ 6$_8$
36	26471	241	408	403	1522	1521	+ 0$_8$
37	22707	148	362	359	1594	1580	— 1$_8$
38	20926	171	271	303	1295	1448	—14$_8$
39	17321	329	218	218	1230	1316	+12$_8$

[1] Now Mr. C. H. Wickens, F.I.A.; F.S.S.; etc.

(i) Age.	(ii) Mothers.	(iii) MSB.	(iv) Twins.	(v) Calc.	(vi) T.M.	(vii) Calc.	(viii) M.T.
40	14086	260	197	166	1404	1185	+ 2
41	9698	157	98	102	1011	1053	— 5
42	8323	168	84	77	1009	922	— 4
43	5645	277	41	35	726	790	+23
44	3374	—75	29	22	860	658	+17
45	2004	—55	11	11	549	527	+12
46	907	—144	6	4	661	395	–
47	424	425	0	1	0	264	–
48	201	900	1	0	498	132	–
49	62	1936	0	0	0	0.3	–
50	14	1429	0	0	0	–	
51	6	3333	0	0	0	–	
52	3	10000	0	0	0	–	
53	1	—10000	0	0	0	–	
54	0						
55	1						

Column (ii) gives for each "age last birthday" the cases of maternity occurring in the six years 1920 to 1925. Among these were the mothers of the twins shown in column (iv). The masculinity of the whole of the single births, for each year of age, is given in column (iii), and is headed MSB. Column (v) is the number of twins calculated by the formulae hereinafter given. Column (vi) is 100,000 times the ratio of the cases of twins to the cases of maternity. Column (vii) gives the ratios as calculated by the formulae just referred to. Column (viii) is 1,000 times the masculinity (total males less total females divided by the sum of the two) not for the individual years, but of groups of seven, five and three years, as indicated by the small number. The value is always assigned to the middle year of the group.

5. *The masculinity of single births according to the age of the mother.*—In order to ascertain whether for births generally the masculinity is a function of the mother's age or not, it was necessary to take out the quantity for each year of age. As the results gave no definite indication, they were taken out for about five-year groups, that is the groups were treated as wholes. The result was as follows:—

Table VII. Group masculinities for single births, Australia, 1920 to 1925.

Age-group	12-16	17-19	20-24	25-29	30-34	35-39	40-43	44-46	47-55	12-55
Masc. × 10000	317	207	289	271	255	219	216	—79	+75	259.1
Calculated	320.4	305.2	290	271	252	238	217.9	?	?	

The calculated values are linear, and indicate a reduction of 3.8 per 10,000 per year of age; but they do not fit groups 17-19, 44-46, and 47-55. The value for the 18-19 group is 295.7; by calculation 303.3; it may be said therefore that, generally, the masculinity slightly decreases with age during the important years of the child-bearing period, but that it is subject to very considerable oscillations; or, in other words, is very irregular. The magnitude of these irregularities cannot be explained by defective statements as to the ages of the mothers. It would appear therefore that the masculinity may be taken to be 259 per 10,000 for single births, and has no very definite trend.

From table VI it will be noticed that the number of cases of maternity are large, and that for single births therefore the probability of its conforming to a fixed value is small; it would rather appear that the tendency to the production of an excess of males is subject to relatively large modifications, notwithstanding that it is persistent.

Initial and final numbers of cases of maternity.—The initial numbers of maternity cases are, (age 12), 6, 26, 171, 513, 2106, etc.; and the final ones are, (age 45), 2004, 907, 424, 201, 62, 14, 6, 3, 1, 0, 1, the last for age 55. These would have to be smoothed in order to express the law of increase and of diminution. It is sufficient here to notice that rates dependent upon such small numbers are not well determined. It may also be noted that 12 is probably not the true commencing age of maternity, nor 55 the true terminating age. Coghlan mentions a birth at 58 in New South Wales.

6. *Law of frequency according to age in the production of twins.*—An examination of the values of the ratios of cases of twins to cases of maternity revealed the fact that they are very nearly linear, and are well represented by the formulae:—

(2) ... $t = \quad +0.000585(x-10)$; up to age 37, inclusive;
(2a) ... $t' = 0.015795 - 0.001316(x-37)$; & from age 37 to age 49

Then the actual number of twins is given by Ct or Ct'. How closely the formulae represent the facts, is shown on Fig. 1, on which the straight lines denote the formulae and the dots the actual numbers. A comparison of the observed and calculated numbers of cases of twins will show that the initial and final divergencies from the straight lines are of no moment, and do not impair the law stated.[1]

The extraordinary precision of the linear law is shown not merely by the striking agreement of the actual and the calculated numbers for each year of age of the mothers, columns (iv) and (v) of Table VI, but also by the sum totals up to every age. These, commencing with age 13, are as follow:—

Actual	1	2	5	16	38	92	213	347	552	818	1155	1504	1941	2384
Calculated	0	0	2	9	32	87	186	333	540	807	1135	1513	1929	2381

Actual	2858	3319	3840	4385	4843	5329	5812	6268	6687	7090	7452
Calculated	2851	3347	3850	4387	4855	5353	5816	6266	6690	7098	7452
Actual	7723	7936	8133	8231	8315	8356	8385	8396	8402	8402	8403
Calculated	7755	7963	8139	8241	8318	8353	8375	8386	8390	8391	8391

The final figures are for age 48.

For the years 1907 to 1914, an almost identical result was found, the values as calculated being as follow:—

Period.	Age 15	20	25	30	35	37	
1907-14	190	506	823	1139	1456	1582.5	Ratios × 100,000
1920-25	292	585	877	1170	1462	1579.5	

These results raise the question as to whether the frequency according to age is a function of time or not. To test this more definitely, the nuptial and ex-nuptial results for 1907-14 were combined and the ratios found for all twins. The results are as follow, and the 1920-25 ratios are placed with them for purposes of comparison.

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[1] This law was discovered by me and given in the Mathematical Theory of Population, see "Nuptial and ex-nuptial probability of twins according to age." See also Fig. 83 therein, and the text, pp. [illegible]-311. The linear constants were very nearly the same; the period to which the results refer was 1907 to 1914. Combining the ex-nuptial with the nuptial cases, the result was $t=0.000638(x-12)$.

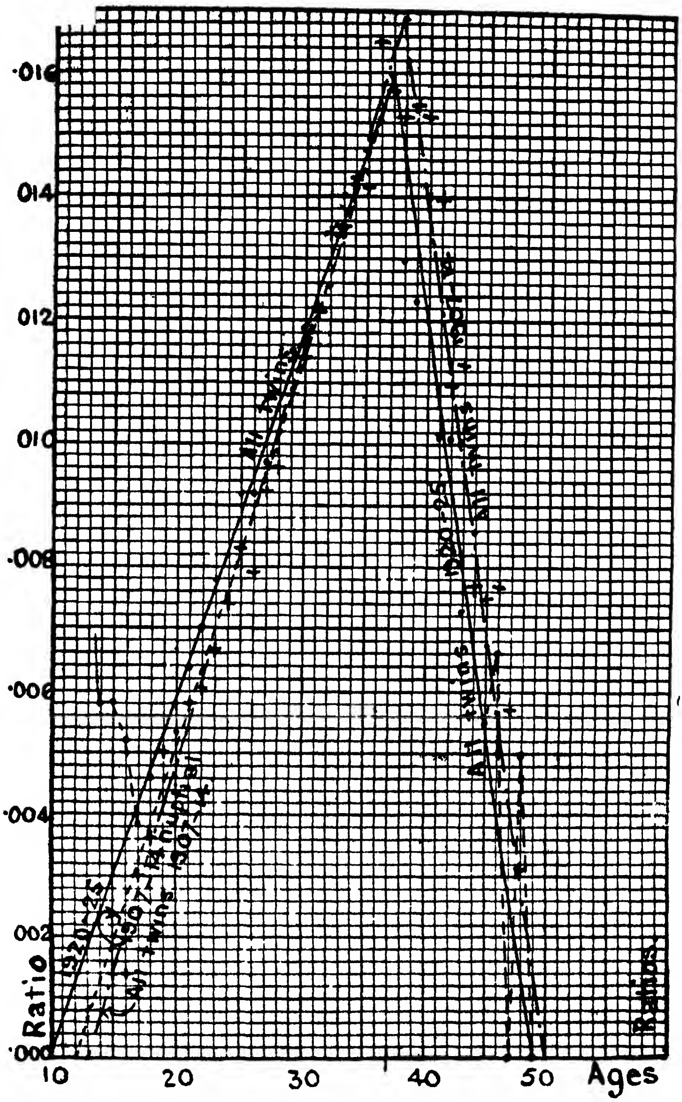

Fig. 1.
Ratios of cases of twins to cases of maternity according to age of mother.

Table VIII. Changes of ratios of cases of twins to cases of maternity, with time: 1907-14, 1920-25.

Ages	14	15	16	17	18	19	20	21	22
1907-14 ..	0	141	140	303	364	500	572	582	605
1920-25 ..	585	585	522	385	460	648	535	637	699
Ages	23	24	25	26	27	28	29	30	31
1907-14 ..	666	738	833	792	922	963	1079	1139	1213
1920-25 ..	781	756	922	919	971	989	1152	1187	1203

Ages	32	33	34	35	36	37	38	39	40
1907-14 ..	1342	1355	1431	1414	1655	1573	1527	1550	1538
1920-25	1257	1405	1422	1446	1522	1594	1295	1230	1404

Ages ..	41	42	43	44	45	46	47	48	49	50
1907-14	1397	1097	1130	766	747	772	571	310	0	0
1920-25	1011	1009	726	860	549	661	0	498	0	0

The ratios are multiplied by 100,000.

7. *Fluctuation with time of frequency according to age.*—The differences of the ratios shown in the preceding table are obviously not merely accidental. They may be taken as referable to the epochs 1911.0 and 1923.0; that is the change, if systematic, is the change in 12 years. The results are graphed on Fig. 1, the individual results being shown by crosses, and their general values, according to the formulae hereunder, by the line—on the figure—broken by dots. The formulae are:—

(3)... $t = \quad -0.0006775(x-13)$; up to age 38 inclusive;
(3a).. $t' = 0.0169375 - 0.0014114(x-38)$; & from age 38 to age 50.

The crude ratios for 1920-25 are greater up to age 30 inclusive, for ages 31, 32, 34, and 36 they are less; for 33, 35, and 37 they are greater; then for 38 to 47 they are less. Following the formulae, viz., (2) and (3), the results are equal for age 31.973, say age 32. Thus we may say that for 1923.0 the probability of twins is greater for any age up to 32, than it was in 1911.0, and for ages greater than 32 it is less than in 1923.0. The changes in the probabilities for the two epochs are linear for ages 12 to 37 and 38 to 49. This is very obvious by reference to the figure. Further research in 10 years' time is desirable, and also in other lands at the present time.

8. *Sex-dist[illegible]tion in the case of twins.*—A case of twins m[illegible]ugh the fertilisation of a single ovum, and it[illegible]bseq[illegible]nt division into two, (uniovular twins); or th[illegible]the fertilisation of two ova, (diovular twins). In the former case they are (said to be) *invariably* of the

same sex (both males or both females); in the latter case they may be of either sex or of both sexes.

Bearing in mind the fact of masculinity, the probabilities —of distribution according to sex—may perhaps best be seen as follows:—Consider first the diovular twins. The probable distribution will be:—

$4D$ children born as diovular twins..	(MM)	(MF)	(FM)	(FF)
i.e. $2D$ cases of twins	$D(1+\nu)$ +	D +	D +	$D(1-\nu)$ children

in which ν is the masculinity as between the (MM) and (FF) cases only, that is, ignoring the existence of the (MF) and (FM) cases altogether. Let the masculinity over all, that is including the males and females born as (MF) and (FM), be denoted as μ: then we have at once $\mu = \frac{1}{2}\nu$. Consider next the uniovular twins. Their distribution will be, obviously:

$2U$ children born as uniovular twins ..	(MM)	(FF)
i.e., U cases of twins	$U\,(1+\lambda)$ +	$U\,(1-\lambda)$; children;

λ being the masculinity. There will be no cases of (MF) or (FM).

A priori, it might seem that one ought to assume in this last case that λ is equal to μ; on the ground that the mere subdivision of the ovum would not (probably) affect the relative number of males and females that would reach maturity. This reasoning, however, would lead to the expectation that the masculinity of twins would be the same as that for "all births" and "first births". We have seen from tables IV and V that for twins it averages only 168 per 10,000; while for all births and for first births it was respectively 257 and 277. One therefore is in doubt as to what assumption ought to be regarded as the most probable. This, however, does not touch the question as to what is the ratio of the uniovular to the

total cases of twins. From the probabilities of the $2D$ cases, we see that if the totals of 2 males, male and female, and 2 females, are respectively M, P, and F; then, so far as the diovular cases are concerned, $\mathrm{P} = \mathrm{M}' + \mathrm{F}'$ say; consequently the number of uniovular cases is $M + F - P$, and their ratio to the whole of the cases of twins is (4)......$\xi = (M + F - P)/(M + F + P)$, the formula previously given.[1] This relationship, then, is not in any way affected by what one deems to be the possible relations between λ, μ and ν. Thus we note that the masculinity μ is an *observed* ratio, and that the proportion of uniovular cases depends upon an elementary and apparently *inescapable assumption.* For testing the assumption, it may be noted that we have the following data:—

	Total	(MM)	(MF)	(FF)		
German Empire 1906-11	154444=	49425+	58382+	46637.	μ=0.01805;	ξ=0.24397
Australia 1920-25	8403=	2792+	2989+	2622.	μ=0.02023;	ξ=0.28859

Actual observations of a relatively small number of cases by Weinberg[2] and Ahlfeld[3] gave somewhat lower values for the proportion of uniovular cases, viz., ϕ0.21 and 0.172 respectively. The masculinities are closely in agreement and are definitely less than the masculinity generally; and the proportion of uniovular cases is very nearly the same. It would appear that they may be supposed to be about one-fourth of the total cases of twins.

Though the totals are to hand for the double male, male and female, and double female cases of twins, and though also the uniovular and diovular totals are determinable,

[1] Journ. Roy. Soc. N.S.Wales, vol. lix. p.133.

[2] Beiträge zur Physiologie und Pathologie der Mehrlingsgeburten beim Menschen. Archiv f.ges. Physiol. 1901, lxxxviii, 846; Neue Beiträge zur Lehre von den Zwillingen. Zeit.f. Geb.u. Gyn. 1903, xlviii, Hft.l.

[3] Zeit. f. Geb. u. Gyn. 1902. xlvii. 280.

the analysis as between the uniovular and diovular distributions of males and females is dependent upon the conclusion arrived at concerning the relation of the masculinities λ, μ, and ν. If we assume that $2\mu = \nu$, which is at least very probable,[4] we have the data for solution, as is evident from the probabilities of distribution according to sex, indicated earlier in this section. Some conception of the arithmetical effect can be had by solutions from the Australian data now available. These, which did not exist earlier, are as follows:—

Class of Cases.	Totals.	(MM)	(MF)	(FF)	(MM)	(MF)	(FF)
Uniovular cases .	2425	1237	0	1188	1250.58	0	1174.42
Diovular cases ..	5978	1555–	2989	1434	1541.42	2989	1447.58
Total cases twins,	8403	2792	2989	2622	2792.00	2989	2622.00

The *data* are the figures given in the bottom line, i.e., the total cases of twins. The masculinity over all is 0.0203, if we accept that as, in all probability, covering both classes of cases, then we get the solution on the left hand. If, however, we put the pairs out of consideration in ascertaining the masculinity, it then is 0.0314, and if this be applied to the uniovular twins, and also to the (MM) and (FF) cases of diovular twins, then we get the solution on the right hand. The former I think the most probable. Though they do not differ greatly the differences are appreciable.

One may conclude that though the proportion of uniovular cases and the masculinity are well determined, there is less certainty about the dissection of the cases, because the question of the applicability of the accepted masculinity to the two classes of cases is one subject to much uncertainty.

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4 That is that the masculinity of the uniovular cases, is identical with that of the diovular cases, over all, an assumption which it was pointed out, gave this relation.

9. *Fluctuation of masculinity, according to age of mothers.*—The data for the determination of the masculinities of the groups of twins according to the age of the mothers, is given in table IX later, and this permits also the ascertainment of the proportion, according to age, of the number of uniovular cases.

Table IX. Sex-distribution of twins, according to the ages of the mothers; their masculinities and proportions of uniovular cases; Australia, 1920 to 1925 inclusive.

Age	MM	MF	FF	μ	μ'	ξ	ξ'
13	0	0	1	—			
14	0	0	1				
15	1	0	2		—35		
16	4	1	6	—66	—33	577	569
17	8	4	10	+ 3	—30	532	536
18	25	7	22	—27	—25	553	504
19	39	33	49	—21	—20	518	474
20	56	36	42	—17	—14	510	446
21	73	42	90	—13	— 8	468	419
22	95	73	98	+ 7	— 1	445	394
23	120	99	118	+13	+ 7	412	371
24	127	108	114	+18	+15	375	349
25	149	144	144	+25	+23	343	329
26	152	152	139	+14	+30	315	310
27	152	166	151	+23	+40	290	293
28	156	171	139	+21	+50	273	278
29	171	192	158	+57	+58	253	263
30	197	209	139	+48	+63	251	252
31	145	170	143	+68	+56	229	241
32	166	195	125	+33	+43	201	232
33	154	185	144	+39	+29	236	225
34	148	164	144	+17	+17	233	219
35	128	172	119	+ 6	+ 6	221	215
36	118	162	123	± 0	± 0	186	213
37	105	148	109	— 1	— 6	230	212
38	95	89	87	—14	—12	210	213
39	62	97	54	+12	—12	239	215
40	58	73	66	+ 2	—10	201	219
41	[illegible]	33	32	— 5	— 5	266	225
42	28	33	23	— 4	+ 2	265	232
43	11	18	12	+23	+ 9	262	241
44	11	8	10	+17	+17	251	252
45	3	5	3	+12	+26	256	263
46	2	0	4				
47	0	0	0				
48	0	0	1				

Note.—The group-values for the masculinity and for the proportion of uniovular twins depend upon 7 groups for ages 16, 17, 18; upon 5 groups for ages 19, 20, 21, 22; on 3 groups for ages 23 to 41 inclusive; upon 5 groups for ages 42, 43, 44; and upon a 7 group for age 45. The group-value is assigned in the table to the middle year of the group, but is of course not necessarily the value attributable to that age. μ and ξ are multiplied by 1000.

Curve A, on Fig. 2, shows the smoothed values in the table for the masculinity and the dots show the group-values, multiplied by 1,000, in the table, drawn opposite to the middle years, which is sufficiently exact except for the terminals. Although they pass over a considerable range they show clearly that masculinity varies systematically with age, changing from femininity (negative masculinity) at about age 22 or 23; becoming a maximum at age 30; becoming zero again at about age 36; then remaining negative till age 41 or 42; and finally again becoming positive. Actually for small numbers the results are very divergent; and for a good determination of the law of the phenomenon a very much longer series of observations will be required. In the table μ denotes the masculinity as found; μ' denotes the smoothed values. Similarly the proportion of uniovular cases as found is denoted by ξ, and the smoothed values by ξ'.

Fluctuation of the proportion of uniovular cases with the age of the mothers.—If the values in the (MM), (MF), and (FF) columns of table IX be smoothed and plotted, one gets the curves marked B or M.M; C or M.F; and D or F.F; on Fig. 2. It is immediately evident from the figure, that the relative numbers of the three classes of twins vary systematically with the age of the mothers. It is equally evident on comparing the *5-year totals of the groups*, which are:—

Ages ..	12	17	22	27	32	37	42	47	Middle year of group.
MM ...	0	77	471	780	810	508	141	5	Double-male twins.
MF	0	45	358	825	923	668	165	5	Male and female twins.
FF	2	89	462	731	695	492	143	8	Double-female twins.

The totals, which we analysed earlier, were 2792, MM; 2989, MF; and 2922, FF. There are very nearly in the ratios, 140.1; 150.0; 131.6. If such ratios obtained at each age, then the curves B, C, D, in the figure would be similar; curve D would be the bottom curve; curve B the middle curve; and curve C the upper curve. The distances between them would change regularly, and of course the curves would never intersect. The differences of the actual curves, from the similar curves just described, are such that they cannot be attributed to small numbers or minor irregularities. Thus we see that *in the case of twins the relative frequency of the production of males and females is, within human beings, a function of the age of the mothers.*

No very simple formula gives very exactly the proportion of uniovular twins as a function of the age of the mother, but it is remarkable how closely on the whole the values, found for ξ, conform in a general way to the parabola.

$$(5) \;\ldots\ldots\; \xi' = 0.212 + 0.00081\;(x - 37)^2.$$

This parabola is shown on Fig. 2 as curve E. It is not the best general representation of the results: this latter is curve F, which consists of a second degree curve from ages 18 to 27; of a parabola[1] from 27 to 37; and again of a parabola from 37 to 45.[2] The results are very remarkable, for they appear to show that, as the frequency of the occurrence of twins increases, the proportion of diovular cases diminishes, that is, of course, if the fundamental assumption of the probability of the uniovular cases and of the diovular, is as stated in the former section. One sees, too, that the range of frequency in the uniovular cases is from over one-half to a little over one-fifth, the latter, more exactly 0.207, occurring at the age, 37, viz.,

[1] The parabola is $0.207 + 0.00087\;(x - 37)^2$.

[2] The second parabola is $0.207 + 0.0015\;(x - 37)^2$.

that of the maximum frequency of the occurrence of twins. The age-coincidence of the two phenomena is also a fact well worthy of notice, apart from any question of its proper interpretation, for it corresponds to a real relation, viz., that between say

$$t_x/C_x \text{ and } (M_x + F_x - P_x)/(M_x + F_x + P_x),$$

see equation (4), section 8.

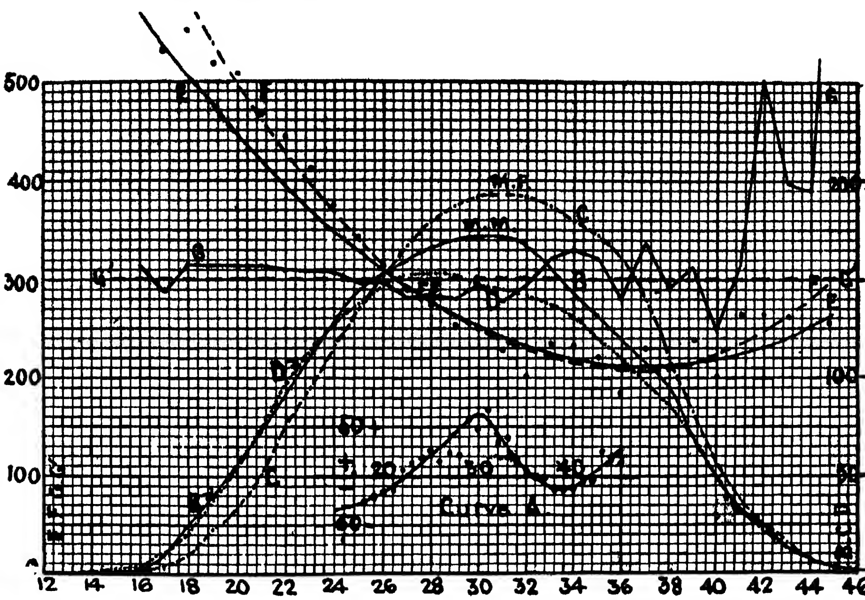

Fig. 2.

Curve A— Smoothed values of Masculinity, over all, of twins: dots are the group-values for the central ages. Curve B or M M.—Smoothed values of numbers of two-male twins. Curve C or M F.—Smoothed values of numbers of male and female twins. Curve D or F.F. (fine dotted line).—Smoothed values of numbers of two female twins Curve E E., parabola and curve F.F.—Smoothed values of proportions of uniovular twins to total numbers Curve G.G —Ratios of uniovular twins to cases of maternity. G'G'—Line of average value.

10. *Relation between the proportion of uniovular cases, and the relative frequency of the occurrence of twins.*—In order to reveal clearly the nature of the relation referred to, the values of the curve F, multiplied by 1,000, and shown by broken lines on Fig. 2, are given in table X, hereinafter. Beneath them are the calculated values of

the rate of the occurrence of cases of twins, based upon the number of cases of maternity.[3] To show in a simple way their relation, the first three significant figures of the products of the two, are given beneath them. These products show very exactly the nature of the correlation between the frequency of the bearing of twins, and the frequency of the division of the human ovum into two, after fertilisation, according also to the age of the mother. The reciprocal nature of the relation is thus immediately manifest.

Table X. Proportions of uniovular twins, and twin-ratios, to maternities, according to the ages of the mothers; and the products of the two rates. Australia, 1920 to 1925.

Ages	19	20	21	22	23	24	25	26	27
Uniovular proportions	534	497	463	430	399	369	341	315	294
Twin-ratios to m. ..	526	585	644	702	760	819	878	936	994
Products of ratios ..	281	291	298	302	303	302	299	295	292
Ages	28	29	30	31	32	33	34	35	36
Uniovular proportions	277	263	250	238	229	221	215	210	208
Twin-ratios to m. ..	1053	1112	1170	1228	1287	1346	1404	1462	1521
Products of ratios ..	292	292	292	292	295	297	302	307	316
Ages	37	38	39	40	41	42	43	44	45
Uniovular proportions	207	208	213	221	231	244	261	281	303
Twin-ratios to m. ..	1580	1448	1316	1185	1053	922	790	658	527
Products of ratios ..	327	301	280	262	243	225	206	185	160

Note.—The values of the uniovular proportions are multiplied by 1,000, and those of the twin-ratios by 100,000.

Since these products are equivalent to $(M + F - P)/C$ for each age, it is perhaps not remarkable that the number of uniovular cases, as compared with the number of cases of maternity, are sensibly constant for ages 19 to 37, that is up to the age of maximum relative frequency in the production of twins. Obviously this product should be examined directly by dividing the uniovular cases by the corresponding cases of maternity. This will now be done.

11. *Ratio of uniovular cases of twins, to cases of maternity.*—This ratio, found directly for each year of age, is, owing to the smallness of the numbers, so variable

[3] See column vii., table VI.

that it was deemed better to form groups of 3 to 7, and attribute the group-result to the middle year of the group. In table XI the ratios, so found, multiplied by 100,000 are given. The number of cases of maternity are: ages 12 to 37, 726,205; 38 and over, 82,946; total, 12 to 55, 809,151. The corresponding uniovular cases are respectively, 2186, 239, and 2425. The ratios over all are:—12-37, 0.003010; 37-55, 0.002881; and 12-55, 0.002997. The mean of the products, in the bottom line of table X, ages 20-38, is also 0.002997. From age 40 onward the differences are appreciable; from age 20 to age 38 they are in very close agreement. Thus taking them in threes we have, for 20-22, 23-25, etc., the last result being for age 38 only:—

Direct values	314	304	287	285	315	314	292
From products	296	301	293	292	298	317	301

Table XI. Frequency of cases of uniovular twins, in cases of maternity, occuring at each year of age; based on 809,151 cases of maternity, and 8403 cases of twins; Australia, 1920 to 1925.

Age	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Ratio	315	287	316	315	316	316	311	308	308	297	297	280	385	281	296
Age	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**
Ratio	278	294	321	331	322	281	339	292	312	248	315	503	398	390	700

The ratios are multiplied by 100,000.

These results are shown by the irregular line G—G, and the result over all by the line G′—G′. They depend upon such relatively small numbers that the deviations from the average have but little significance, which can be readily verified arithmetically.[1] It cannot reasonably be expected that there should be a very close agreement between the two results, i.e., between the individual age-results and the result over all. One therefore is justified

[1] Suppose the correct data were 40,000 maternities; MM, 145; MF, 170; FF, 145. If the total remain the same for the sum of the three, but the number of pairs be altered to 169; that is if the data be 145, 169, 146, the ratio is altered from 300 to 305.

in arriving at the conclusion that *the probability of the giving birth to twins, through the division of an ovum after fertilisation, is approximately the same throughout the productive period of female life;* that is, it bears approximately a constant ratio, to the number of cases of maternity, of three in a thousand, 0.003. Since the probability of twins based upon maternity increases up to age 37 and then diminishes, it follows that:—relatively to the number of twins, the number of cases of uniovular twins is a minimum at age 37. This fact is noteworthy, because *the fertilisation of two ova, and the division of ova into two, are apparently, therefore, quite independent facts.* Thus the result is important biologically.

If one accepts the two results, viz., that the frequency of twins is expressed by formulae (2) and (2a), section 6, and that the ratio of uniovular cases to cases of maternity is constantly 0.003, then a table can be very readily constructed, giving the relative frequency of uniovular and diovular cases for each year of age from say 12 to 55. Masculinity as between the MM and FF cases appears to be much more uncertain, and the uncertainty of any *a priori* tabulation of it would be considerable.

12. *The frequency of triplets, in relation to maternity.*—From table I, it was obvious that the frequency of triplets is subject to a large measure of uncertainty. For their distribution according to age we have results for the years 1916 to 1925, say, 10 years. These are given in table XII hereunder. With such limited numbers, totalling only 132, if one wishes to discover the general law of distribution according to age, obviously it is essential that the results should be smoothed. This has been effected in such a manner that the resultant distribution is regular, differs as little as possible from the individual results, and so also that the accumulated differences from the accumulated sum

of the individual results, shall be as near as possible a minimum.

As there was a slightly larger average number of twins annually in 1916-1919, than in 1920-25, it was sufficiently exact to use as the divisor, the number of cases of maternity in the latter period, multiplied by 1.666667. These numbers of cases are already given in table VI, section 3a. In this way we find the ratios of the occurrences of triplets to cases of maternity, for each age during child-bearing. It is not necessary to graph these results: it can be seen immediately from the table that a smooth curve has been obtained with the same total, and differing very little at any age from the data.

In the table, the ratios of cases of triplets are given, for each age, per million cases of maternity of the age in question. They lie on a curve of the type of the normal curve of probability, differing in this respect from the frequency of twins according to age. The maximum is at age 35, instead of age 37, as with twins. This may be due to the paucity of the numbers available, but is *not* due to any limitations in the scheme of smoothing.

Table XII. Ten–year totals of the actual number of triplets at each of their mothers; their smoothed distribution; and their ratios, per million cases of maternity at the same age. Australia, 1916 to 1925.

Age	No.	S.No.	Ratio.	Age	No.	S.No.	Ratio.
15 ..	0	0.0	0	27 ..	3	5.5	70
16 ..	0	0.1	29	28 ..	7	6.2	79
17 ..	1	0.3	31	29 ..	7	7.0	93
18 ..	1	0.6	31	30 ..	10	7.9	103
19 ..	0	1.0	32	31 ..	9	8.9	140
20 ..	1	1.4	33	32 ..	9	9.7	151
21 ..	1	1.8	34	33 ..	6	9.9	173
22 ..	4	2.3	36	34 ..	12	9.8	183
23 ..	4	2.9	40	35 ..	10	9.2	190
24 ..	3	3.6	47	36 ..	10	8.3	188
25 ..	4	4.2	53	37 ..	7	7.0	185
26 ..	4	4.8	60	38 ..	6	5.3	152

Age	No.	S.No.	Ratio.	Age	No.	S.No.	Ratio.
39 ..	2	3.9	135	44 ..	0	0.7	124
40 ..	4	2.9	124	45 ..	0	0.4	120
41 ..	1	2.2	136	46 ..	0	0.3	198 ?
42 ..	4	1.6	115	47 ..	0	0.2	597 ?
43 ..	2	1.1	117	48 ..	0	0.0	0

These ratios have been multiplied by 1,000,000.

As of course might be expected with so few cases, the ratios do not lie exactly on a regular curve and the results for ages 46 and 47 cannot be regarded as reliable. The values generally are sufficient to show that the probability is a function of age; that it reaches a maximum at about age 35; and that it then diminishes. In this respect it is analogous to the case of twins, but it does not increase and diminish linearly, as did their probability.

13. *Sex-distribution of triplets.*—The sex-distribution of triplets is available for only 70 cases in Australia, and is as follows:—Total cases 70. MMM, 24; MMF, 16; MFF, 9; FFF, 21. The masculinity over all is thus 0.0762: between the MMM and FFF cases only, it is 0.1429: between the MMF and MFF cases 0.933. In table V it was shown that the masculinity over all varied greatly from year to year. The numbers are too small for any analysis to be of value.[1]

14. *Quadruplets.*—Between 1890 and 1925 there were only six cases of quadruplets in Australia. The relative frequencies of maternities, twins, triplets, and quadruplets were given in table III.

Maternities ..	4,012,181;	Twins, 40,998;	Triplets, 379;	Quadruplets, 6
Ratios ..	1,000,000;	10,281;	94.46;	1.50
German Empire	1,000,000;	12,856;	128.95;	1.332

[1] This could be carried out on the lines indicated in a "Note on the occurrence of triplets among multiple births. Jour. Roy. Soc. N.S. Wales, lx, pp. 278-282." It might be preferable perhaps to assume that the masculinity μ applied to each of the three groups, at the foot of p. 279, therein.

Besides this Germany had 0.25 quintuplets per million confinements.

15. *Conclusions.*—The following are the conclusions that are reached:—

(i) Among Australians (and probably with all of similar race) the ratio of twins to cases of maternity increases sensibly linearly from zero at age 10 to 0.01580 at age 37: it then decreases also sensibly linearly, and somewhat more rapidly to age 49, becoming then zero.

(ii) The relative distribution of cases of two males, male and female, and two females, is a function of the age of the mothers. The curves of frequency for the three cases, though of somewhat similar form generally, do not, for each age, preserve the ratios which they bear to one another when the cases are taken as a whole.

(iii) Among twins, the proportion of uniovular cases is a function of the ages of the mothers, and is a minimum for sensibly the same age as that at which the ratio of twins to cases of maternity is a maximum. The curves representing this function are sensibly parabolas.

(iv) The ratio of the number of uniovular cases to that of the cases of maternity, is sensibly the same for each year of age during the reproductive period of female life. It is not, contrary to what one might have anticipated, proportional to the frequency of the cases of twins.

(v) The relative frequency of the subdivision of fertilised ova is uniform for each year of female reproductive life: it has no dependent relation upon the frequency according to age of the simultaneous fertilisation of two ova.

(vi) Masculinity in cases of multiple births is irregular and is not readily predictable.

(vii) Since the frequency of births with all never married, widowed, and divorced females, taken together, is at exact age 21.3; for all births occurring within nine months of marriage, is at exact age 21.4; and for all first-births is at exact age 23.2; the greatest frequency in the production of twins is in no way related, correlatively, to the age of the most effective gonad urge in the human female.

(viii) The available record of numbers of triplets being restricted to 10 years and 132 cases, smoothing of the distribution was necessary. It appears certain that the frequency of the occurrence of triplets is a function of the age of the mothers, the maximum being at about age 35, and about 0.00019. The distribution-curve is probably asymmetrically bell-shaped, and certainly is not similar to that in the case of twins.

(ix) Only 70 cases are available for the sex-distribution in the case of triplets, this being MMM 24; MMF 16; MFF 9; and FFF 21, and thus it is normal in respect of masculinity.

(x) In Australia, quadruplets number only 3 in two million cases of maternity: no data exist permitting of an analysis of their mode of occurrence.

(xi) The *graphing* (a) of the frequency of the ratios of twins to maternities, shows immediately the very remarkable suddenness of the change at age 37; (b) of the frequency of uniovular cases to cases of maternity, and that this is *not* a function of the age of the mother; (c) of the curves of frequency of the occurrences respectively of two males, of male and female, and of two females, that this *is* a function of the age of the mother, and is not a simple one. The graphing of the masculinity of twins according to the mothers' ages shows that it changes from

negative to positive, becomes negative again, and finally becomes positive.

(xii) The fundamental assumption upon which the analysis of twins into uniovular and diovular cases depends, is that, excepting insofar as it is modified by masculinity, the diovular MM, MF, FM, and FF cases will be equal in number. That being so, if the total number of cases of two males and two females, be reduced by the total number of cases of pairs, the remainder will be the number of uniovular cases. This assumption is, apparently, not merely inescapable, but is also fairly well supported by Weinberg's and Ahlfeld's direct observations of smaller numbers.

STUDIES IN THE INHERITANCE OF RESISTANCE TO LEAF RUST, *PUCCINIA ANOMALA* ROSTR., IN CROSSES OF BARLEY. I.

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(With Plates IV.-V.)

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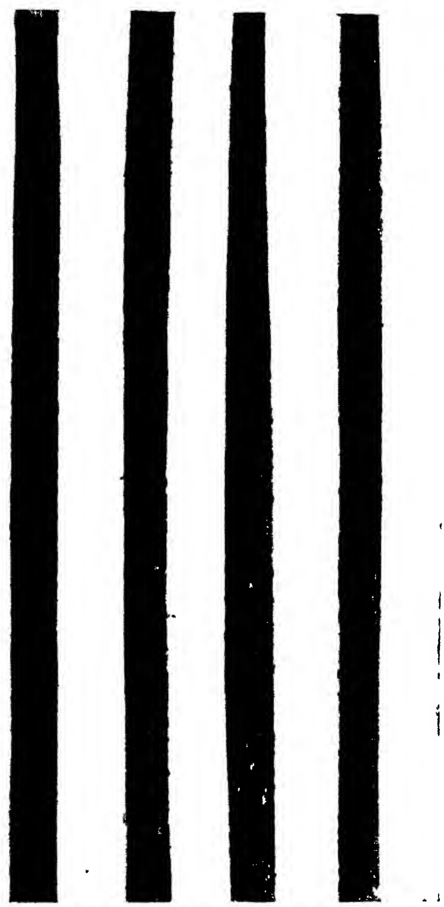
INTRODUCTION.

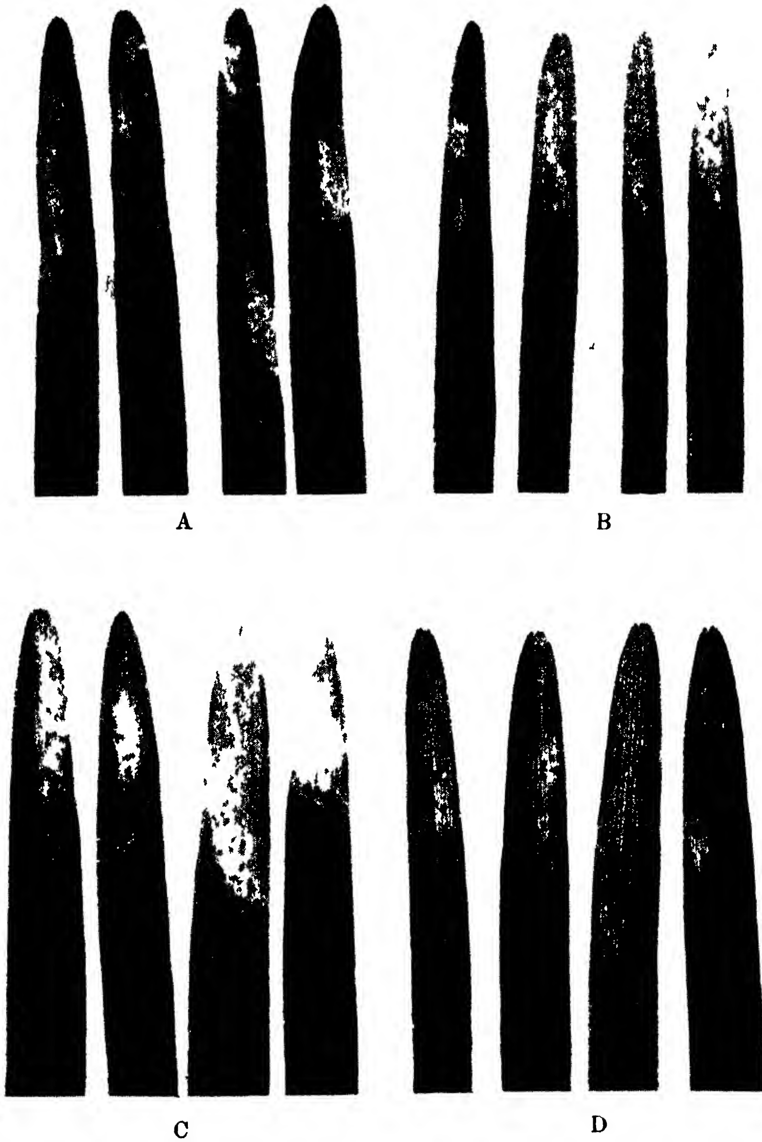
Cereal rusts cause very heavy crop losses, and from the earliest days have received considerable attention. The most promising method of reducing losses is by breeding rust-resistant varieties. An understanding of the inheritance of resistance to rust thus becomes important.

The first recorded genetical study of the inheritance of resistance to disease was made by Biffen (6, 7, 8 & 9). He found that the susceptibility of certain wheats to yellow stripe rust (*Puccinia glumarum* Erikss) behaved as a simple Mendelian dominant character; the results showed a ratio of 3 susceptible plants to 1 resistant in the F_2 generation. Nilsson-Ehle (29, 30) working with other wheat varieties infected by this rust, obtained results which were not so simple, but explainable on the basis of multiple factors. Armstrong (4) carried out investigations with this same rust and confirmed Biffen's results.

The most extensive studies of rust resistance deal with stem rust of cereals and grasses caused by *P. graminis* Pers. Results have been reported by Hayes, Parker and Kurtzweil (19), Waldron (36), Puttick (33), Aamodt (1, 2, 3), Melchers and Parker (27, 28), Hayes and Stakman (20), Garber (13, 14), Griffee (15), Hayes and



Four stems of "Cape" barley from a naturally infected crop growing at Hawkesbury Agricultural College, N.S.W., showing the teleutospore stage of *Puccinia anomala* Rostr. attacking the leaf sheath.



Representative barley seedling leaves illustrating 4 classes of reaction to the leaf rust. In each case two leaves show the upper and two show the lower surfaces. All were photographed 12 days after inoculation.

A, Highly resistant, styled the "O" reaction.
B, Very resistant, styled the "1" reaction.
C, Moderately resistant, styled the "2" reaction.
D, Very susceptible, styled the "4" reaction.

Aamodt (21), Harrington and Aamodt (17), Barker and Hayes (5), Harrington (18), Hayes, Stakman and Aamodt (23), Clark (10), Dietz (12) and Hynes (24). The results are very varied. This is to be expected where such an extremely specialised pathogen and such a wide group of host plants are concerned. A general discussion is withheld until later in the paper.

The inheritance of resistance to leaf rust of wheat, *P. triticina* Erikss., has been studied by Mains, Leighty and Johnston (26).

Parker (31, 32) and Davies and Jones (11) have studied the inheritance of resistance in oats to crown rust, *P. coronata* Cda.

The results of studies on the inheritance of resistance to leaf rust of rye, *P. dispersa* Erikss. and Henn. have been reported by Mains and Leighty (25).

Apparently no study has yet been reported of the inheritance of resistance to the leaf rust of barley, *P. anomala* Rostr. Frequently this fungus heavily attacks the commercial varieties of barley which are grown for green feed in the coastal regions of New South Wales (Plate IV.). An investigation was therefore undertaken, of which only the results obtained in the glass house are herein reported. Barley is also susceptible to stem rust, *P. graminis tritici* E. and H. Work dealing with this rust will be reported later in another paper. The studies herein described are divided into two sections (1) varietal tests and (2) cross-breeding results.

MATERIALS AND METHODS.

Several collections of *P. anomala* occurring on barley crops were made. Cultural tests in the glass house using some of the commercial varieties of barley which are usually grown gave no indication of physiological specialisation of

the fungus. But it is not improbable that further tests with a wider range of host varieties may reveal the presence of more than one physiologic form of the rust. The glass house studies herein reported deal with only one physiologic form. The culture used was obtained from material collected by Mr. G. S. Gordon at the Werribee Research Station, Victoria. No other culture of the rust was grown in the glass house throughout the course of these investigations.

Barley crops in the coastal areas of New South Wales have always, when examined, proved to be more or less heavily infected by the leaf rust as they approach maturity. Although the attack in some cases has been severe and the loss considerable, there is no recorded case of the crop having been completely ruined. But if similar varieties to "Cape" and "Skinless", resistant to the leaf rust could be obtained, a good work would be accomplished. A search was therefore commenced for a variety or varieties resistant to the rust.

Grain of as many varieties as possible was obtained from different sources. About a dozen grains of each were sown in pots and the first leaf of the seedlings used in the tests. Where any doubt existed about the result, sowings were replicated until definiteness was reached.

The tests were made in the usual way by moistening the leaf with distilled water and then introducing to the moistened area a quantity of the inoculum upon a sterile flat needle. When first used, the strain of rust had been subcultured in the glasshouse for at least 50 uredospore generations on a susceptible variety of barley. After inoculation the pots were incubated in a saturated atmosphere at ordinary glasshouse temperatures for 48 hours. Preliminary tests showed that incubation for 24 hours gave results essentially similar to those obtained

from the longer incubation. The longer period of 48 hours was adopted in order to bring this barley leaf rust work into conformity with the usual glasshouse routine, which deals mainly with stem rust; the best result with this latter rust is given by 48 hours incubation. After removal from the incubation chamber, the pots were placed in well lighted positions on the glass house benches to allow the rust to develop. Light and temperature variations markedly affected the rate of development. Tests using the same rust on the same varieties in cool dull winter weather and in bright hot summer showed that normal development of pustules took place in 14 days under the former, as compared with 8 days under the latter conditions.

Notes on the reactions given by the plants were taken when infection was best developed on the susceptible control plants. As already stated, this period varied from 8 to 14 days. The following classes of rust reaction were recognised, depending upon the type of infection produced on the leaves:—

Table 1.—Leaf rust reactions used in the determination of resistance or susceptibility.

Notation.	Class of Reaction.	Type of Reaction.
0.	Highly resistant	No uredosori produced; flecks of a necrotic nature present.
1.	Very resistant	Uredosori few in number, small, and always produced in the centre of necrotic spots; frequently many of the hypersensitive areas show no sori.
2.	Moderately resistant..	Uredosori fairly abundant, of fair size and always produced in necrotic or very chlorotic areas.
3.	Moderately susceptible.	Uredosori fairly abundant, of moderate size and produced in areas which show no necrosis, although sometimes slight chlorosis occurs.

4. Very susceptible	**Uredosori abundant, large and produced without necrosis or chlorosis. Occasionally a chlorotic ring occurs round the pustule.**

Classes 0, 1, 2 and 4 are illustrated in Plate V.

The strict differentiation between certain of these classes was difficult, e.g., between "1" and "2", and especially between "3" and "4". But the distinction between the resistant and the susceptible classes could always be made. On account of this difficulty, and because results in the first of the crosses studied (A. Cape x Manchuria) indicated that a change from "0" to a "1" reaction was not of genetic significance, in a good deal of the work the notes were taken to record either resistant or susceptible reactions, without specifying the particular class to which the resistant individuals belonged. It appears that a change from a "0" to a "1", from a "1" to a "2", or from a "3" to a "4" class of reaction may be brought about in some cases by simply giving better environmental conditions of light and temperature for development of the rust. But in other instances, under extremely varied conditions, certain barley types showed striking necrosis (i.e., a "0" reaction) and only this reaction. Throughout the work the class of reaction referred to by Stakman and Levine (34) as the "heterozygous or X class" was not met.

EXPERIMENTAL RESULTS.

1. VARIETIES.

The varieties subjected to the glasshouse tests are here grouped according to the classification of Harlan (16). The origin of the seed is stated in each case. Those indicated by a Cereal Investigation Number (C.I. No......) were mostly supplied by Principal E. A. Southee of Hawkesbury Agricultural College, who obtained them from Dr. H. V. Harlan of U.S.A. Drs. H. K. Hayes and J. J. Christensen supplied seed of a number from

Minnesota. Mr. G. S. Gordon of the Werribee Research Station, Victoria, contributed a number. The greatest number, however, came from Mr. J. T. Pridham of the Cowra Experiment Farm, who has always been most generous with his material.

As already stated, in these tests about a dozen plants of each variety were used. Where any doubt existed as to the class of reaction, further sowings were made and the tests repeated until definiteness was reached.

The results are set out in the following tables:—

Table 2.—Results with varieties of *Hordeum vulgare* L.
(a) Susceptible. Reaction = "4".

	Variety.	Source.
C.I.2202	*H.v. nigrum typica* (Black Russian)	U.S.A.
C.I.2204	*H.v. atrum typica*	,,
C.I.2206	*H.v.. duplinigrum typica*	,,
C.I.2201	*H.v. trifurcatum typica* (Nepaul) ..	,,
C.I. 908	*H v. pallidum* (Luth)	,,
C.I. 991	*H.v. cocleste*	,,
C.I.2238	*H.v. nigrum leiorrhynchum* (Lion) ..	,,
C.I.2256	*H.v. pallidum rikotense*	,,
C.I.2269	*H.v. pallidum eurylepis*	,,
Sel. C 81	Manchuria	Minnesota
Sel. C225	Manchuria	,,
	Trabut	Cowra, N.S.W.
	Cape	,,
	Skinless	,,
	Reka	,,
	Shorthead	,,
	Chilian	,,
	Albert	,,
	Mariout	California
	Four Thousand	,,
	No. 78	Cowra, N.S.W.
	Gold	,,
	Hero	,,
	White Hulless	,,
	Meloy	Cowra, N.S.W.
	Pearl	,,
	Chedret	,,
	Coutsopodi	,,
	Janina	,,
	Larissa	,,
	Kaylaria	,,
	Senes	,,
	Salonika	,,

	Variety.	Source.
	Zea	Cowra, N.S.W.
	Sahara 3763	„
	„ 3764	„
	„ 3765	„
	„ 3766	„
	„ 3767	„
	„ 3768	„
	„ 3769	„
	„ 3771	„
	Tennessee Winter	Werribee, Victoria.
	Himalaya	„
	Orzo nuda putignans	„
	Orzo maraina	„
	Gatami	„
	Tunis	„
	Sea of Azov	„
	White Hulless	„
	Roseworthy Oregon	„
	Wisconsin Pedigree	„
	Squarehead	„
	Odessa	„
	(b) Moderately resistant. Reaction = "2".	
	Californian Feed	Cowra, N.S.W.
	Psaknon	„
	Locride	„
	Sahara 3770	„
	Coast	„
	Marionet	Werribee, Victoria.
	Orge Fourragère	„
	Minn. I 16.18 Lion	Minnesota, U.S.A.
	Minn. II 20.10 B	„
	Minn. II 21.14	„
	(c) Resistant. Reaction = "0" or "1".	
C.I.2208	*H.v. aethiops typica*	U.S.A.
C.I.2290	*H.v. horsfordianum typica* (Virginia Hooded)	„
	Minn. II 21.15 Smooth Awn x Manchuria	Minnesota
	Minn. II 21.17 Smooth Awn x Manchuria	„
	Minn. II 21.18 Smooth Awn x Manchuria	„
	Sel. C163 Manchuria	„
	Sel. C168 Manchuria	„
	Minn. 184 Manchuria	„
	Manchuria	„
	O.A.C. 21	Cowra, N.S.W.
	No. 22	„
	No. 305	„
	Colsess	„
	Orge 4th	Werribee, Victoria
	Orge 14J	„

Table 3.—Results with varieties of *Hordeum intermedium* Kcke. Susceptible. Reaction = "4".

	Variety.	Source.
C.I.2209	*H.i. haxtoni typica*	U.S.A.
C.I.2210	*H.i. mortoni typica*	"
C.I.2213	*H.i. nudihaxtoni typica*	"
C.I.2214	*H.i. nudimortoni*	"
C.I.2215	*H.i. cornutum typica*	"
C.I.2237	*H.i. haxtoni tonsum*	"
C.I.2254	*H.i. haxtoni tonsum*	"
C.I.2280	*H.i. haxtoni tonsum* (Arlington Awnless)	"
	"Intermediate"	Cowra, N.S.W.

Table 4.—Results with varieties of *Hordeum distichon* L.
(a) Susceptible. Reaction = "4".

	Variety.	Source.
C.I.2219	*H.dis. angustispicatum typica*..	U.S.A.
C.I.2221	*H.dis. nudum typica* (McEwan's)..	"
C.I.2222	*H.dis. nigrinudum*	"
C.I.2223	*H.dis. laxum typica*	"
C.I.2224	*H.dis. nigrilaxum*	"
C.I.2250	*H.dis. nudum ianthinum*	"
	Princess	Cowra, N.S.W.
	Goldthorpe	"
	Primus	"
	Standwell	"
	Kinver	"
	Pryor	"
	Cowra 27	"
	Volga	"
	Golden Grain	"
	Gisborne	Werribee, Victoria
	H. distichon nutans	"
	H. distichon erectum	"
	Hanchen	"
	Duckbill	"
	Burton's Malting	"
	Binder	"
	Garton's Regenerated Malster ..	"
	Archer	"

(b) Resistant. Reaction = "0".

C.I.2220	*H.dis. rimpaui typica*	U.S.A.

Table 5.—Results with varieties of *Hordeum deficiens* Steud. Susceptible. Reaction = "4".

	Variety.	Source.
C.I.2225	*H.def. deficiens typica*	U.S.A.
C.I.2226	*H.def. steudelii typica*	"
C.I.2228	*H.def. tridax typica*	"
C.I.2229	*H.def. nudificiens typica*	"

In addition to these tests of varieties of the cultivated barleys, tests were made of two other species of *Hordeum* which were available. One of these was "Wild Barley", *Hordeum spontaneum* Koch., obtained from Dr. H. V. Harlan in the U.S.A. It proved to be completely susceptible to the rust, giving the typical "4" reaction. The other was "Barley Grass", *Hordeum murinum* L., which was resistant, giving a sharp "0" reaction.

An examination of these results shows that of the cultivated varieties tested, no one belonging to *H. intermedium* or *H. deficiens* proved resistant, and only 1 of *H. distichon*. Of *H. vulgare,* 15 varieties were found to be strongly resistant, and 10 varieties were moderately resistant.

Comparison of varietal resistance to Leaf Rust and Spot Blotch.

An interesting point is that some of the strains of "Manchuria" are susceptible to leaf rust, whilst others are resistant. This is in agreement with the results of the study of the resistance of these barleys to attack of *Helminthosporium sativum* Pammel, King, and Bakke, as reported by Hayes et al, (22). This organism causes Spot Blotch of barley. A direct comparison of the two results is possible in some cases, thanks to Drs. Hayes and Christensen who forwarded grain of some of their pure lines. In the following table are shown the reactions of these barleys to the two pathogens. The "H. No." is that showing the reaction to *Helminthosporium* found by Hayes et al. (22). A high figure, of which 30 is the maximum, denotes very high resistance, whilst a low figure, of which 3 is the minimum, denotes complete susceptibility.

Table 6.—Comparison of the resistance of certain Barleys to *Puccinia anomala* and *Helminthosporium sativum*.

Variety.	Reaction to *P. anomala*.	Reaction to *H. sativum*.
Manchuria C81.. ..	"4"=Susceptible	H. No. = 16.0
Manchuria C225. ..	"4"= do.	H. No. = 7.0
Minn. I. 16.13 Lion.	"2"=Moderately resistant	H. No. = 10.0
Minn. II. 20.10 B ..	"2"= do. do.	H. No. = 21.5
Minn. II. 21.14.. ..	"2"= do. do.	H. No. = 23.0
Minn. II. 21.15.. ..	"0"=Very resistant	H. No. = 20.0
Minn. II. 21.17.. ..	"0"= do.	H. No. = 20.0
Minn. II. 21.18.. ..	"0"= do.	H. No. = 20.5
Manchuria C163 ..	"0" do.	H. No. = 21.0
Manchuria C168 ..	"0" do.	H. No. = 19.5
Manchuria Minn. 184	"0" do.	H. No. = 21.0

It will be noted that in general, varieties resistant to leaf rust are also resistant to *Helminthosporium sativum*, and those which are susceptible to rust are also susceptible to *Helminthosporium sativum*. An exception is Manchuria C81. The correlation is slight also in the case of Minn. I. 16.13 Lion. It is difficult to suggest any common morphological basis for the resistance to these two pathogens, and no work has been undertaken relative to physiological resistance.

The varietal tests show that there are available several barley varieties which are resistant to the leaf rust. But as so often happens, these resistant varieties in themselves have certain failings in N.S.W. from an agronomic point of view, as for example, late maturity, low yield and poor stooling capacity. Hence cross-breeding work was undertaken involving these resistant varieties and good agronomic sorts which are susceptible to the rust.

2. CROSS-BREEDING RESULTS.

In 1923 and in each succeeding year a number of crosses were made at the University of Sydney between susceptible commercial varieties like Cape, Skinless and Kinver, and certain of the varieties which have been shown to be resistant, e.g., Manchuria, *H. distichon rimpaui typica* and

Virginia Hooded. These crosses were tested in the F_1, F_2, and F_3 generations. During all the work, frequent sowings were made of each of the parents concerned, and these seedlings tested for resistance as controls alongside the cross-bred seedlings. The F_1 grains were sown in pots, and after being tested the seedlings were transplanted to open ground and grown to maturity. In the F_2 generation the same procedure was followed. In many cases additional F_2 grain was sown directly in open ground, and these plants harvested at maturity without having been tested as F_2 individuals.

At harvest time it was found convenient to pluck heads of individual plants into paper bags which were then labelled. These were later strung in order on wire. Loss of grain from shattering of the heads was thus avoided and thorough drying-out facilitated.

A. Cape x Manchuria.

F_1 Results.

From the cross, 17 grains were secured. Sixteen of these F_1 seedlings gave a "0" reaction, and one of them gave a "4" reaction. Control inoculations of the parents gave a "4" reaction on "Cape" and a "0" reaction on "Manchuria". It thus seemed that 16 were true crosses and that the one susceptible plant was the result of accidental self-pollination. Each F_1 plant at maturity was harvested separately. The susceptible plant did not show any marked agronomic differences from the others. Ninety seedlings were grown from it. All proved susceptible, thus confirming the idea that accidental pollination had occurred in this instance.

Rejecting this result, therefore, it is clear that resistance is dominant. Moreover the resistance of the F_1 plant is similar to the resistance of the resistant parent. Intermediacy of reaction is not shown.

F_2 Results.

Grain from two of the F_1 plants was sown in boxes and each resultant F_2 plant inoculated with the rust. After notes had been taken, the seedlings were transplanted to open beds, each under its proper number which was retained throughout the F_3 tests. Grain from the other F_1 individuals was sown directly in open ground and the individual F_2 plants harvested at maturity. These plants, therefore, were not tested in the F_2 generation.

The results of the F_2 tests are shown in the following table:—

Table 7.—Reactions of plants tested in the F_2 generation.

Plant Breeding Number.	Number of Resistant Plants. Reaction = "0".	Reaction = "1".	Number of Susceptible Plants. Reaction = "4".
II. 23.1.1	79	21	33
II. 23.1.2	55	18	21
Totals	134	39	54

From this table it will be seen that the resistant plants were divided into two classes, viz., "0" and "1", on the basis of the rust reaction exhibited. As already pointed out in connection with the varietal tests, a change from one class to the other may sometimes be brought about by an alteration of the environmental conditions. The control pots of the resistant parent (Manchuria) gave a "0" reaction usually, but occasionally the reaction was "1" It was thought that the "1" reaction of the F_2 segregates might be an index to the heterozygosity of these individuals. In other words, these plants might be the intermediates. But in the F_3 tests, some of the families derived from F_2 plants which gave a "0" reaction, proved to be homozygous for resistance, whilst others were heterozygous for this character. Exactly the same thing occurred with families derived from F_2 plants showing a "1" reaction. A close

scrutiny of the figures showing the number of individuals producing the "0" and "1" reactions in a number of the families, failed to indicate any genetic significance. Clearly then, intermediacy of reaction is not shown in this cross.

The results of these F_2 tests may therefore be summarised as 173 resistant and 54 susceptible seedlings. This is an approximation to a 3:1 ratio. On the basis of one genetic factor difference between resistance and susceptibility, the expectancy would be 170:57. The deviation is 3 and the probable error on the basis of 227 individuals is 4.4.*

$$\frac{\text{Deviation}}{\text{Probable error}} = \frac{3}{4.4} = 0.68.$$

At maturity the F_2 plants showed a certain amount of diversity in regard to time of maturing and stooling capacity, but otherwise morphological segregation was not marked.

F_3 Results.

The series of 227 tested F_2 seedlings was transplanted into open beds and grown to maturity. Attack by larvae of the "army worm" shortly before harvest time seriously reduced the yield and completely destroyed some of the plants. For this reason there are included in these results some of the F_3 families which had not been previously tested as F_2 individuals. Such families were purely random selections. Individual F_2 plants were harvested separately. For the F_3 tests a number of grains of each was sown. Of some families only a few grains were available, but results are included only where at least 20 grains were sown. In some cases more than 50 grains were sown. Throughout the tests, control pots of each parent were sown and tested, giving the typical "4" reaction for "Cape", and "0" for "Manchuria."

* Probable errors of the Mendelian ratios were obtained from the tables of probable errors from the Department of Plant Breeding, Cornell University.

The families tested fell into three groups. One group was homozygous for resistance, the second heterozygous for resistance, and the third homozygous for susceptibility. There were 66 homozygous resistant families, 117 heterozygous resistant families and 52 homozygous susceptible families. The average number of tested individuals in each family was slightly more than 25. In all, 5986 plants came under test. The 66 homozygous resistant families comprised 1688 individuals, the 117 heterozygous resistant families comprised 2218 resistant and 752 susceptible individuals, and the 52 homozygous susceptible families comprised 1328 individuals. In every case where an F_2 test had been made, the last-named class came from susceptible F_2 parents. The homozygous and heterozygous resistant classes were derived from resistant F_2 parents.

These classes approximate to a 1:2:1 ratio, which is to be expected on a one-factor hypothesis. This is supported by an examination of the totals given by the heterozygous resistant families. The observed ratio is 2218 resistant: 752 susceptible plants. The expectancy on the basis of 2970 individuals is 2226 : 744. The deviation on the basis of a single factor difference is 8 individuals. The probable error is 18.14 individuals.

$$\frac{\text{Deviation}}{\text{Probable error}} = \frac{8}{18.14} = 0.44.$$

B. Manchuria x *Skinless.*

F_1 Result.

From this cross 8 grains were obtained. The F_1 seedlings all gave a "0" reaction, whilst the parents gave respectively "0" and "4". The F_1 plants were somewhat bearded and produced hulled grain.

F_2 Result.

A series of 210 F_2 seedlings was tested, and afterwards these were transplanted to open ground and grown to

maturity. The F_2 test gave 159 resistant and 51 susceptible plants. The particular class of resistant reaction was not noted in individual cases. This result closely approximates to a 3 : 1 ratio. The expectancy on the basis of a single factor difference is 157 : 53. The deviation is 2 and the probable error for 210 individuals is 4.23 individuals. $\frac{\text{Deviation}}{\text{Probable error}} = \frac{2}{4.23} = 0.47$. Test pots of the parent varieties gave the usual reactions. In the open beds the F_2 generation was somewhat attacked by the army worm and its numbers depleted at harvest time.

F_3 Results.

For the F_3 tests, 140 families were used. Prior to sowing, notes were taken on head characters of the F_2 plants, dealing with beardedness or hoodedness, and with hulled or naked grain. "Manchuria" is bearded with hulled grain, and "Skinless" is hooded with naked grain. In recording notes on the F_2 plants, the true naked-grained and the true bearded classes were carefully determined. In the "hulled grain" class were included intermediate types, i.e., those showing a tendency to shell, but not completely naked. Similarly there are included in the "hooded" class intermediate types showing slight beard. The results showed 100 hooded : 40 bearded, which approximates to a 3 : 1 ratio. There were 104 hulled : 36 naked-grained plants, a still closer approximation to a 3 : 1 ratio. Unfortunately it has not been possible to grow these families on to maturity to obtain confirmation of this F_2 analysis for morphological characters.

The F_3 tests showed that there was a group of 33 families, each homozygous for resistance. There was a second group of 60 families, each heterozygous for resistance. A third group of 46 families was homozygous for susceptibility. On an average there were about 23

tested individuals in each of the families. The total number of plants tested was 3359. The 33 homozygous resistant families comprised 753 individuals, the 60 heterozygous resistant families comprised 1126 resistant and 376 susceptible plants, and the 46 homozygous susceptible families comprised 1104 individuals. It is interesting to compare the observed number of the individuals in the heterozygous families with the expectancy. Assuming a single genetic factor difference between resistance and susceptibility, the expectancy on the basis of 1502 individuals is 1126.5 resistant to 375.5 susceptible plants. This is an extraordinarily close fit.

Combining these rust results with those for the morphological characters, the following is obtained:—

Table 8.—Inheritance of three Mendelian characters which are seemingly inherited independently.

Phenotypes.	Expected.	Observed.
Resistant, hooded, hulled	59.1	51
Susceptible, hooded, hulled	19.7	27
Resistant, bearded, hulled	19.7	18
Resistant, hooded, naked	19.7	13
Susceptible, bearded, hulled	6.6	9
Resistant, bearded, naked	6.6	11
Susceptible, hooded, naked	6.6	9
Susceptible, bearded, naked	2.2	2
	140.2	140

It is realised that the number of individuals here dealt with is small, but the results point to the characters being independently inherited.

C. *Manchuria* x *Kinver*.

F_1 Result.

From the cross 16 grains were obtained. The F_1 seedlings were tested alongside the parent varieties, with the result that all showed a "0" reaction. The F_1 plants at maturity were bearded two-rowed plants having hulled grain.

F_2 Result.

In the F_2 generation a series of 194 seedlings was tested. The result was that 147 were resistant and 47 susceptible. This is an approximation to a 3 : 1 ratio. On the basis of a single factor difference the expectancy is 145 : 49. The deviation is 2 and the probable error 4.07.

$$\frac{\text{Deviation}}{\text{Probable error}} = \frac{2}{4.07} = 0.49.$$

After being tested, these F_2 seedlings were transplanted to open beds and grown to maturity. At harvest it was found that the yield in many cases was very poor, so that only a small quantity of grain from some families was available for the F_3 work.

F_3 Result.

In the F_3 tests, 97 families were used. There proved to be a group of 29 homozygous resistant families, a group of 48 heterozygous resistant families, and a group of 20 homozygous susceptible families. The average number of individuals in each of the tested families was rather more than 16. The total number of plants tested was 1605. The 29 homozygous resistant families comprised 465 individuals, the 48 heterozygous resistant families comprised 611 resistant and 208 susceptible plants, and the 20 homozygous susceptible families comprised 321 plants. Again there is the approximation to a 1 : 2 : 1 ratio which is to be expected on a single genetic factor basis. Examination of the heterozygous families confirms this. They comprise 611 resistant : 208 susceptible plants. The expectancy is 614 resistant : 205 susceptible. The deviation is 3 and the probable error 8.36 individuals.

$$\frac{\text{Deviation}}{\text{Probable error}} = \frac{3}{8.36} = 0.36.$$

D. Virginia Hooded x *Cape.*

Four grains were obtained from the cross. The F_1 reaction was "0". In the F_2 test, 171 seedlings were tested and gave a ratio of 121 resistant : 50 susceptible plants. On the basis of a single genetic factor difference the expectancy is 128 : 43. The deviation is 7 and the probable error is 3.82 individuals.

$$\frac{\text{Deviation}}{\text{Probable error}} = \frac{7}{3.82} = 1.83.$$

For the F_3 tests there were available 99 families. These tests showed that there were three groups. There was a group of 25 homozygous resistant families, a group of 50 heterozygous resistant families, and a group of 24 homozygous susceptible families. The average number of individuals in the families tested was about 22. There were 2188 plants in these tests. The 25 homozygous resistant families comprised 518 plants, the 50 heterozygous resistant families comprised 858 resistant and 284 susceptible plants, and the 24 homozygous susceptible families comprised 528 plants. The close approximation to a 1 : 2 : 1 ratio is evident. The heterozygous families show a ratio of 858 resistant and 284 susceptible plants. The expectancy on a single factor difference is 856 : 286. The deviation is 2 and the probable error is 11.59 individuals.

$$\frac{\text{Deviation}}{\text{Probable error}} = \frac{2}{11.59} = 0.17.$$

E. Cape x *Hordeum distichon zimpaui typica.*

Three grains were obtained from the cross. The F_1 reaction was "0". In the F_2 test, 165 individuals were tested, giving a ratio of 123 resistant : 42 susceptible plants. The expectancy on the basis of a single genetic factor difference is 124 : 41. The deviation is 1 and the probable error for 165 individuals is 3.75.

$$\frac{\text{Deviation}}{\text{Probable error}} = \frac{1}{3.75} = 0.267.$$

For the F_3 tests there were available 145 families. They fell into three groups. There was a group of 42 homozygous resistant families, a group of 69 heterozygous resistant families and a group of 34 homozygous susceptible families. The average number of individuals in the tested families was about 20. The total number of plants tested was 2860. The 42 homozygous resistant families comprised 828 individuals, the 69 heterozygous families comprised 1046 resistant and 357 susceptible plants, and the 34 homozygous susceptible families comprised 629 individuals all of which were susceptible. The heterozygous families show a ratio of 1046 resistant : 357 susceptible individuals. On the basis of a single genetic factor difference the expectancy is 1052 : 351. The deviation is 6 individuals and the probable error is 11 individuals.

$$\frac{\text{Deviation}}{\text{Probable error}} = \frac{6}{11} = 0.55.$$

SUMMATION OF RESULTS OF THE CROSSES.

If it is assumed that the resistance in each of the cases reported is due to the one factor, it becomes interesting to add the results of the several crosses.

In the F_2 tests of the 5 crosses, 975 plants were used. The results are set out in the following table:—

Table 9.—Summation of the F_2 results in all 5 crosses.

Cross Number.	Parents.	Number of Individuals in Tested F_2 Generations.	
		Resistant.	Susceptible.
II. 23.1	Cape x Manchuria	181	54
II. 23.6	Manchuria x [illegible]	159	51
II. 23.7	Manchuria x Kinver	147	47
II. 23.8	Virginia Hooded x Cape ..	121	50
II. 23.9	Cape x *H. dist. rimpaui typica*	123	42
	Totals	731	244

On the basis of a single genetic factor difference, the result shows a deviation of less than 1 individual from the expectancy where 975 individuals are concerned.

In the F_3 tests of the 5 crosses, 715 families were dealt with. These comprised 15998 plants. Thus there was an average of rather more than 22 tested individuals in each of the families. The results are shown in the following table:—

Table 10.—Summation of the results of the tests of the F_3 families in all 5 crosses.

Cross Number.	Parents.	Number of F_3 Families Tested.		
		Homozygous Resistant.	Heterozygous Resistant.	Homozygous Susceptible.
II. 23.1	Cape x Manchuria..	66	117	52
II. 23.6	Manchuria x Skinless	33	60	46
II. 23.7	Manchuria x Kinver	29	48	20
II. 23.8	Virginia Hooded x Cape	25	50	24
II. 23.9	Cape x *H. dist. rimpaui typica*	42	69	34
	Totals	195	344	176

On the basis of a single factor difference, the expectancy would be 178.75 : 357.5 : 178.75.

Table 11.—Summation of individuals in the F_3 heterozygous families of all 5 crosses.

Cross Number.	Parents.	Resistant.	Susceptible.
II. 23.1	Cape x Manchuria	2231	760
II. 23.6	Manchuria x Skinless	1126	376
II. 23.7	Manchuria x Kinver	611	208
II. 23.8	Virginia Hooded x Cape	858	284
II. 23.9	Cape x *H. dist. rimpaui typica* ..	1046	357
	Totals	5872	1985

On the basis of a single factor difference, the expectancy for 7857 individuals is 5893 : 1964. The deviation is 21 and the probable error is 28 individuals.

$$\frac{\text{Deviation}}{\text{Probable error}} = \frac{21}{28} = 0.75.$$

DISCUSSION.

The results herein reported show that resistance to leaf rust of barley (*Puccinia anomala* Rostr.) is inherited in certain varietal crosses in a very definite manner. It is Mendelian in character. Moreover it is dependent upon a single genetic factor which is dominant to the allelomorphic factor for susceptibility. The observed results upon which this generalisation is based show a striking approach to the expectancy.

It is instructive to review briefly the results which have been reported dealing with the genetics of inheritance of resistance to cereal rusts.

In the investigations of inheritance of resistance to Yellow Stripe Rust of wheat, *P. glumarum* E. and H., Biffen (6, 7, 8, & 9) found in the crosses of certain varieties, a simple ratio of 3 susceptible plants : 1 resistant. Resistance in these crosses was due to a single genetic factor which was recessive. It was inherited independently of other observed morphological characters. Armstrong (4) obtained substantially similar results. Nilsson-Ehle (29 & 30) used different parental varieties and did not obtain such clear-cut results. In the F_2 generation he found transgressive segregation and various types intermediate in resistance between the parents. He considered that his results were only to be explained upon a multiple factor hypothesis.

The inheritance of resistance of wheats to Leaf Rust, *P. triticina* Erikss., was studied by Mains, Leighty and Johnston (26). They found some cases in which resistance was dependent upon a single dominant genetic factor. In other cases it was dependent for its expression upon a single main factor difference. In yet others it was demonstrated that more than one genetic factor was concerned.

Many workers have investigated the inheritance of resistance to stem-rust in wheat, *P. graminis tritici* E. and H. Hayes, Parker and Kurtzweil (19) found that resistance to a physiologic form of the rust was dominant in crosses between varieties of *Triticum vulgare* and *T. dicoccum*, whilst it was recessive in crosses between varieties of *T. vulgare* and *T. durum*. In the latter there were strong linkages between rust resistance and "durum" characters, but some resistant plants of the "vulgare" type were obtained. That is to say, crossing-over took place occasionally. Waldron (36) examined a cross between a variety of *Triticum vulgare* and *T. durum*, and was unable to explain his results on the basis of a single factor for resistance. Puttick (33) reported results of the study of the reactions in glasshouse tests of the F_2 generation of a cross between varieties of *T. vulgare* and *T. durum*, using two physiologic forms of the rust to which the parents reacted reciprocally. He found all gradations between complete susceptibility to and immunity from the two forms of the rust. Melchers and Parker (27 & 28) found that a single genetic factor was responsible for resistance to one physiologic form of the rust in crosses between Kanred and Marquis. Aamodt (1, 2 & 3) working with a cross between these same parents, reported that a single genetic factor apparently determined the reaction to several physiologic forms of the rust. Hayes and Aamodt (21) studied a cross betweeen Kota and Marquis, using two physiologic forms of the rust. The results were explainable on the basis of two independently inherited factors for immunity and resistance contained in the Kota and Marquis parents respectively, each factor being allelomorphic and dominant to the factor for susceptibility. Clark (10) crossed Hard Federation and Kota, and showed that resistance to the rust was recessive. He obtained a

15 : 1 ratio in the F_2 generation, indicating the presence of 2 Mendelian factors for resistance in this cross. In the F_3 generation not one of about 300 resistant F_2 families bred true for resistance, although a number of individual plants did. It was considered that homozygous strains could be obtained in the F_4 generation by selection within the F_3 families. Harrington (18) studied crosses between certain varieties of *T. durum* dealing with resistance to several physiologic forms. He found that several factors were involved and that environmental factors modified the expression of the reaction. Thompson (35) demonstrated that in crosses of Iumillo (resistant) and Marquis (susceptible), a ratio of 13 susceptible : 1 resistant was obtained in the F_2 generation, and that there was very close correlation between "durum" characters and rust resistance. Hayes, Stakman and Aamodt (23) state that the resistance of the "durum" parent can be combined with the characters of the common wheat. In a double cross of (Marquis x Kanred) x (Marquis x Iumillo), the inheritance of 2 types of resistance was studied. A single factor was found to explain the Marquis x Kanred type of immunity, while at least 2 factors were required to explain the Marquis x Iumillo resistance. Hynes (24) studied a cross between Federation (a common wheat) and Khapli (an emmer), obtaining results explainable on a multiple factor hypothesis.

It is not surprising that these reported results dealing with stem rust of wheat should be so varied. The pathogen is very highly specialised. In the U.S.A. more than 40 physiologic forms have been determined, and in Australia the writer has determined several others. In addition to the specialisation of the rust fungus, it must be remembered that the wheats used in the crosses belong in some cases to widely different species of *Triticum*.

The inheritance of resistance to stem rust of oats, *P. graminis avenae* E. and H., was investigated by Garber (13 & 14). He found in crosses of the two susceptible varieties Minota and Victory with White Russian, a resistant parent, that the F_1 plants were as resistant as the resistant parent and that the F_2 generation showed a simple ratio of 3 resistant plants : 1 susceptible. The F_3 generation results confirmed this. There appeared to be no linkage between rust reaction and panicle type. Griffee (15) in similar work obtained results which gave a close approximation to the expectancy on the hypothesis of a single dominant genetic factor for resistance being present. Dietz (12) used 2 physiologic forms of the rust, and found that resistance was dominant and based on a single factor difference in National x White Tartar and in Lincoln x White Tartar. In crosses between 3 genetically different strains of Burt, at least 2 factors,—one of them an inhibitor—were involved. In the crosses Iowa 105 x Green Russian and Ruakura x White Russian, the result in the F_2 was a segregation into 300 resistant plants to 1 susceptible.

Here again there is evidence that resistance does not behave in the same manner in every instance. Clearly there are more factors than one underlying resistance to stem rust of oats.

In a study of rust of Timothy Grass, *P. graminis phlei-pratensis* E. and H. Stak. and Piem., Barker and Hayes (5) demonstrated that the inheritance of resistance was dependent upon a single dominant genetic factor.

Parker (31 & 32) studied the inheritance of resistance in oats to crown rust, *P. lolii-avenae* Mc.A. He concluded that resistance could hardly be considered as a simple character or as being determined by a single factor difference, but was explainable upon a multiple factor

hypothesis. Davies and Jones (11) studied the inheritance of resistance to this rust in a cross between a selection of Red Rust Proof (resistant) and Scotch Potato (susceptible). They obtained a ratio of 777 resistant and 258 susceptible plants in the F_2 generation. Of the resistant segregates, 117 showed a weakening of resistance as compared with the others, which closely resembled the resistant parent. But the results suggested a single factor basis for inheritance.

The inheritance of resistance of leaf rust of rye, *P. dispersa* E. and H., has received some attention from Mains and Leighty (25). The data were insufficient to justify conclusions as to the type of inheritance, but resistance is believed to be dominant.

From a consideration of the foregoing results, it is clear that the inheritance of resistance to various rusts varies in different crosses. In some cases the resistance is dependent upon a single genetic factor. This may behave as a Mendelian dominant in some crosses, as a recessive in others. In other cases the basis of inheritance is far more complex. This applies to yellow stripe rust, leaf rust, and stem rust of wheat, and to crown (leaf) rust and stem rust of oats.

The results herein reported show that in the crosses investigated, inheritance of resistance to leaf rust of barley is dependent upon a single dominant genetic factor. It appears that complete dominance was shown in the F_1 individuals. In the F_2 generation there was segregation not only into the 2 grandparental types, but some individuals appeared which showed an intermediate type of resistance. In the cases investigated, this intermediate type of reaction was not directly correlated with the heterozygosity of the F_2 segregates concerned, as indicated by the F_3 generation results.

Further work is in progress involving crosses which ave been made in each year since 1923, from which it is oped to get additional light on this point. Another uestion concerns the type of inheritance in crosses where ne parent, as for example, "Californian Feed", shows ne "2" type of reaction. These results will be reported n a future occasion.

It is worth while calling attention to the value of barley rosses of this nature for teaching work to illustrate undamental Mendelian principles. The extremely sharp eactions which are given make it particularly useful for he purpose, and no technical difficulties are encountered n any of the operations.

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SUMMARY.

Glasshouse tests have been made with 119 varieties of barley belonging to 6 species to determine their reaction to one Australian physiologic form of *Puccinia anomala* Rostr.

Strong resistance was shown by 16 of them. These varieties belong to *Hordeum vulgare* and *H. distichon.*

None of these varieties is entirely suitable agronomically for N.S.W. conditions.

Crosses of certain of these resistant varieties were made with commercial N.S.W. varieties, and the inheritance of resistance studied throughout the F_1, F_2, and F_3 generations.

In the F_1 generation resistance was completely dominant.

The F_2 result showed segregation in a ratio of 3 resistant plants to 1 susceptible.

The F_3 generation studies confirm the hypothesis that a single dominant genetic factor underlies resistance.

From a few results, evidence of linkage between rust resistance and morphological characters was not found.

Tests of certain varieties seem to indicate correlation between resistance to *Helminthosporium sativum* and leaf rust.

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THE WOOD STRUCTURE OF SOME SPECIES OF KAURI (AGATHIS SPP.)

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(With five text figures.)

(Read before the Royal Society of New South Wales, August 3, 1927.)

At the present time several species of Kauri (*Agathis*) are being used in Sydney and in order to determine whether any reliable method could be found to identify the individual woods, this investigation was undertaken.

The genera *Agathis* and *Araucaria* belong to the Araucarineæ, the wood structure being characterised by the multiseriate pitting of the radial walls of the tracheids, and usually by the absence of bars of Sanio and longitudinal parenchyma in the normal wood. Kanehira* however, records bars of Sanio in *Taiwania,* a genus also included in the Araucarineæ.

The Index Kewensis mentions 24 species of *Agathis;* Dallimore and Jackson† record 15 species, the range extending from the Philippines, through the Dutch East Indies, Papua, New Hebrides, New Caledonia, Fiji, Queensland and New Zealand. Some of these species are evidently small trees and not of importance as timber producers, or do not occur in sufficient quantity to be exported. The principal species which reach Sydney are the Queensland Kauris, *A. robusta, A. Palmerstoni* and *A. microstachya;* Noumean Kauri, *A. lanceolata;* Vanikoro

* Kanehira, Anatomical Characters of Formosan Woods, Taihoku, 1921.

† Dallimore and Jackson, Handbook of the Coniferae, London, 1923.

Kauri, *A. macrophylla,* and to a lesser extent the New Zealand Kauri, *A. australis.* The latter species has always been regarded as the kauri *par excellence,* and in most text-books is the only species cited. It is doubtful, however, whether some of the other species are much inferior in certain respects, and they are certainly far superior to much of the swamp New Zealand Kauri which has been milled and exported.

The woods are light brown in colour (the sapwood is pale), do not possess resin passages, are without very distinctive growth rings and are even in texture. They are thus eminently suitable for all joinery and many other purposes, since they are easily worked, wear well, are moderate in weight, durable, and usually free from knots and other defects, although in common with many other coniferous woods they are not immune from attack by the destructive Furniture Bettle, *Anobium sp.* In general, therefore, the Kauri pines are rightly regarded as a most valuable group of softwood timbers.

The descriptions are based on specimens of the various woods in the Technological Museum collections. The wood of *Agathis robusta* has been described by Baker and Smith* in their exhaustive work on the "Pines of Australia", and excellent photomicrographs are shown of the structure, but it was thought advisable to bring the description into line with those given of the other species.

AGATHIS ROBUSTA, Masters.

Southern Kauri, Queensland Kauri, Dundathu Pine:

A large forest tree occurring over a restricted area in Southern Queensland; at one time was the principal

*** Baker and Smith, "A Research on the Pines of Australia", Sydney, 1910.**

Queensland Kauri, but owing to extensive cutting is not now available in large quantities.

It is a rather woolly, soft, pale brownish coloured, easily worked timber; the sapwood is pale in colour. It is used for interior joinery, framing, panelling, mouldings, turning, light boat building, etc.

Transverse bending tests made recently on 3" x 3" x 36" specimens, centre loading, gave the following mean results:
*f = 6990 E = 913,000 w = 26.6 Moisture = 12.3%
These figures are in close agreement with those given by Baker and Smith (loc. cit.).

Queensland Forest Service, Bulletin No. 2, gives the following:—

f = 4300-6300 w = about 21, Moisture = 11.4%

Macroscopic characters.—Growth rings usually narrow, and well defined on end section, often undulating, transition from early to late wood gradual. Rays brown in colour, easily seen on end section, and especially well-defined on a radial face.

Microscopic characters.—Tracheids, normally hexagonal in section, mean radial diameter 50μ, max. 110μ, min. 18μ, walls 2-4μ in thickness, in late wood up to 7μ; length 1½-8 mm. Radial bordered pits 1-4 rows, usually alternate, but also occasionally opposite in the same tracheid, 11-16μ in diameter; pit openings usually opposed, elliptical, 6 x 3μ. Tracheid plugs† frequently present, especially in tracheids adjacent to medullary rays, often up to 200μ in length. Rays homogeneous, usually uniseriate and rarely biseriate,

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* f = Modulus of Rupture in lbs. per sq. in.
E = Modulus of Elasticity in lbs. per sq. in.
w = Weight per cubic foot at time of test, in lbs.
Moisture = % calculated on dry weight.

† These are usually referred to as "resin plates", but do not consist of resin.

1-24 cells in height. Ray parenchyma cells thin walled, 18-45μ in vertical diameter, up to 300μ in length, contents irregular, brownish, granular or denser and amorphous, 1-4 per mm. of cross section; ray-tracheid pits, 1-16 per section of tracheid, semibordered, border often small, average diameter = 8μ, pit openings usually elliptical, but often irregular in shape, 4-7μ in length. Alkannin gives comparatively little indication of resinous or oily bodies in the ray parenchyma, although small oil globules are present. Growth rings irregular in definition, late wood 1-15 cells in width often with a distinct line of demarcation between it and the early wood; at other times there is a gradation, the junction of early and late wood not being definitely defined.

*Aqueous extract** pale yellow, clear; slightly darkened with ferric chloride; pale yellow with caustic potash, practically no alteration with lime-water.

Burns normally to a grey or brownish-grey fine ash, with little unburnt carbon; one specimen burnt with a very high percentage of unburnt carbon and a small amount of dark coloured ash.

AGATHIS PALMERSTONI, F. v. Mueller.

Queensland Kauri.

A large tree reaching up to 35 feet in girth, found on the coastal ranges and tablelands north from Cardwell, and has now largely replaced *A. robusta* as the Queensland Kauri on the southern markets.

It is a moderately soft, pale to light brown coloured wood, and is used for motor body work, turnery, veneers, interior joinery and fittings, pattern making, etc. It is sometimes used for boat building, but in common with the other Queensland Kauris, is usually considered too soft

*** Obtained by boiling 2g. of shavings in 40 c.c. water.**

for this purpose. Weight per cubic foot, 26-31 lbs., on Museum specimens.

Macroscopic characters. — Growth rings often very irregularly spaced, fairly well defined on end grain, denser wood varying from narrow lines to zones several mm. in width, or at times quite inconspicuous and with practically no variation in appearance between the early and late wood. Rays brown in colour and darker than surrounding tissue, but not prominent in the specimens examined, although easily visible on end section.

Microscopic characters.—Tracheids hexagonal, rounded, oval or almost square in section, very irregular in size and shape; mean radial diameter 55μ, max. 85μ, min. 18μ; walls 2-5μ in thickness; length 3-8 mm. Spiral markings often present on walls. Radial bordered pits in 1-4 rows usually alternate, rarely opposite, average diameter 15μ, pit opening circular to oval or lenticular; tangential pits, few, scattered and rounded, or hexagonal or vertically compressed in 1-2 rows. Tracheid plugs rarely seen. Rays almost entirely uniseriate, outer cells often larger, 1-20 cells in height, cells very thin walled, 15-40μ in height and up to 300μ in length. Ray-tracheid pits semibordered, av. diameter 9μ, 2-12 per section of tracheid; border usually prominent, but often small; pit openings oval to narrow lenticular slits. Rays 2-5 per mm. of cross section. Granular or amorphous, yellowish contents often present, occasionally filling whole of cell cavity. Alkannin shows a small amount of oily or resinous matter to be present, as small globules and irregular masses in the ray parenchyma; small globules occasionally found also in tracheids. Junction of late and early wood marked by considerable radial compression of the tracheid in the former, and by their somewhat thicker walls, the degree of demarcation of the late wood is very variable.

Aqueous extract light brown to brown, clear; darkened by ferric chloride or caustic potash; very pale to pale brown with lime water.

Burns normally to a grey ash with a fair amount of unburnt carbon.

AGATHIS MICROSTACHYA, Bailey and White.

Black Pine.

A large forest tree found at high elevations in the Cairns, Atherton and Herberton Ranges in northern Queensland. The wood is soft, rather spongy, and pale brown in colour. It is apparently sold with *A. Palmerstoni* and is used for the same purposes. Weight 26-32 lbs. per cubic foot. No bending tests available.

Macroscopic characters.—Growth rings usually indistinct, and often only indicated by a slight variation in colour of alternating zones of early and late wood. Rays brown in colour and darker than the surrounding tissue but not prominently so in the material examined.

Microscopic characters.—Tracheids usually hexagonal, often irregularly angular in section; mean diameter 55μ, min. 26μ, max. 80μ, walls 3-7.5μ in thickness in late wood; length 2.4-8.8mm. Radial bordered pits, 1-3 rows; borders hexagonal where crowded to rounded or elliptical where in single rows or scattered; alternate or more rarely opposite, average diameter 15μ; pit openings opposed, oval to narrow elliptical, 6μ in length. Tangential bordered pits scattered or sometimes crowded in 1 or 2 rows, alternate. Tracheid plugs rare in material examined, practically absent in one specimen. Rays homogeneous, uniseriate, rarely biseriate, 1-40 cells in height; cells, average 195μ in length and 18-40μ in vertical height, thin walled, often with brownish granular contents; ray-tracheid pits prominently semi-bordered, 1-15 per section of tracheid, average diameter 7μ; pit openings narrow elliptical to slit-like; rays 2-5 per

mm. of cross section. Alkannin shows a considerable amount of oily or resinous material to be present in the ray cells, usually as irregular masses; starch granules averaging 5μ in diameter are also commonly present. Wood parenchyma occasionally present, diffuse, either isolated cells or in groups of 2 to 4 cells in transverse section; cells up to 300μ in length, thin walled and with well-defined cell contents, consisting largely of starch. Junction of early and late wood usually ill-defined, but seen as a narrow zone of somewhat thicker walled tracheids; there is usually no sharp differentiation between adjacent growth rings.

Aqueous extract yellow to brown, clear, not turbid; turbidity to precipitate with ferric chloride; pale yellow to purple brown with caustic potash; pale yellow to purple brown (precipitate) with lime water.

Burns usually with a grey ash and a large amount of unburnt carbon.

Agathis macrophylla, Masters.

Vanikoro Kauri

A large tree found in the British Solomon Islands and on Vanikoro (La Perouse) Island in the Santa Cruz Group.

The wood is pale brown in colour, firm in texture, and is probably the nearest approach to New Zealand Kauri, of the species described. It is used for motor body work, all kinds of interior joinery, shop and office fittings, baker's troughs, tubs, boat building, turnery, pattern making, etc. It is less spongy than the average Queensland Kauri.

A number of transverse tests have been made, the following being the mean figures:—

(Size of test pieces, 2" x 2" x 24" span; centre load.)

Solomon Islands—

f = 6980, E = 1,076,000, w = 28.7*, Moisture, 28.7%

Vanikoro (material supplied by Wallis Bros. Ltd., Sydney)
f = 12,440, w = 37*, Moisture = 20.0%

Vanikoro (material supplied by R. S. Lamb and Co. Ltd., Sydney)
f = 10,620, E = 1,439,000, w = 38.1*, Moisture, 14.8%

Macroscopic characters.—Growth rings usually indistinct, often very irregular in their spacing, a number of rings converging and separating at random. Rays brown in colour and much darker than the surrounding wood, prominent on a radial face and easily seen on end section.

Microscopic characters.—Tracheids irregularly polygonal, rounded or almost square in section; mean radial diameter 50μ, max. in early wood 95μ, min. in late wood 18μ; walls 3μ in thickness in early wood to 7μ in late wood; length 3-7 mm. Radial bordered pits 1-4 rows, hexagonal where crowded, to flattened oval, usually alternate but occasionally opposite; diameter 11-15μ; pit openings oval to lenticular, opposite. Tangential pits 1-2 rows, appressed or scattered, not numerous. Tracheid plugs numerous, but usually short and not more than 10μ in length. Rays usually uniseriate, but occasionally biseriate, for almost the entire length, practically homogeneous; 1-28 cells in height; 2-5 per mm. of cross section; cells thin walled, 18-40μ in vertical height, 130-220μ in length. Ray pits semibordered, borders usually not pronounced, 2-12 per section of tracheid, average diameter 8μ, pit openings circular or irregularly oval. Cell contents, yellow brown in colour, amorphous or granular, often entirely filling the cavity. Resinous or oily bodies are present to a considerable degree in the ray cells, either as globules or as irregular masses, but are almost absent from the tracheids. Starch granules frequently present

* Weight calculated for 12% moisture.

in the ray cells. Late wood shows a decided radial compression for 1-6 rows of cells, but the junction of early and late wood is often not sharply defined.

Aqueous extract turbid, colourless, opalescent, becoming quite clear with the addition of alcohol; practically no alteration with ferric chloride or at most slightly darkened; no alteration or pale yellow with caustic potash or lime water.

Burns usually to a brownish-grey ash, with a small to medium amount of unburnt carbon.

AGATHIS LANCEOLATA, Pancher.

Noumean Kauri.

A large forest tree, the largest of the three species of *Agathis* recorded by Compton* in New Caledonia. It occurs below 1,000 ft. altitude.

The wood is pale brown in colour, easily worked, rather firmer in texture than the average Queensland Kauri, and is imported to Australia in big quantities. The principal uses are light boat building, motor body work, interior joinery, flooring, lining, mouldings, etc., shelving and general shop fittings, draining boards, tubs, large vats, school desks, wooden parts of agricultural machines, etc.

The following are the results of bending tests on material supplied by Messrs. Davies and Fehon, Ltd., Timber Merchants, Sydney.

Test pieces, 2″ x 2″ x 24″ span, centre load.

min.	f = 8,060	E = 1,537,000	wt† = 34.9	Moisture = 18.0%
max.	f = 11,230	E = 1,843,000	wt† = 36.3	Moisture = 20.8%
mean	f = 9,980	E = 1,701,000	wt† = 35.1	Moisture = 19.1%

3″ x 3″ x 36″ span, centre load.

min.	f = 8,000	E = 1,189,000	wt† = 37.1	Moisture = 16.9%
max.	f = 11,540	E = 1,784,000	wt† = 39.2	Moisture = 18.0%
mean	f = 9,950	E = 1,487,000	wt† = 38.1	Moisture = 17.5%

* Compton, R. H. Plants from New Caledonia, Jour. Linn. Soc. (Botany), xlv, 430, 1922.

† Weight corrected to 12% moisture.

Macroscopic characters.—Growth rings not pronounced, late wood usually seen on end section as narrow undulating zones or even lines. Rays much darker than the surrounding tissue and prominent on a radial face; easily seen on end section.

Microscopic characters.—Tracheids usually irregularly polygonal or rounded; mean radial diameter 50μ, max. 75μ, min. 14μ, in late wood; walls 4-10μ in thickness, very much thickened at corners; length 3.5-9 mm. Radial bordered pits 1-5 rows, hexagonal where crowded, to more or less rounded; usually alternate; mean diameter 14μ; pit openings, oval to lenticular, 11μ in length; tangential pits not numerous, in 1 or 2 short rows, more or less rounded. Tracheid plugs numerous, 3-130μ in length. Rays almost all uniseriate, homogeneous, 1-38 cells in height, but usually not more than 20, 2-5 per mm. of cross section; cells moderately thin-walled, 18-45μ in vertical height, up to 300μ in length. Ray-tracheid pits semibordered, borders distinct, mean diameter 8μ; openings narrow elliptical to slit-like; 1-15 per section of tracheid. Cell contents granular or amorphous, yellow-brown, numerous oily or resinous irregularly shaped bodies shown to be present with alkannin; starch granules numerous. Growth rings sharply defined, due to considerable radial compression and very thick walls of a narrow zone of late wood, from 1-10 cells in width, at its junction with the early wood.

Aqueous extract colourless, very slightly turbid; slightly darkened with ferric chloride; practically no alteration with caustic potash or lime water.

Burns with a grey to brownish-grey ash and a very little unburnt carbon.

AGATHIS AUSTRALIS, Salisbury.

New Zealand Kauri.

A very large forest tree confined to the northern part of the North Island of New Zealand, but owing to extensive cutting is becoming scarce and the timber is now rarely seen on the Sydney market. Its uses are manifold and owing to its durability it is especially used for light boat building, vats, tubs, as well as general joinery, etc., but is now practically replaced in Sydney by the other Kauris. Owing to the shortage, swamp logs have been milled, in some cases with unfortunate results.* The uses and properties are very fully described by Kirk in his Forest Flora†, and a number of mechanical tests are given by the writer in the paper cited. The weight per cubic foot varies from about 30 to 40 lbs.

Macroscopic characters.—Growth rings not prominent on end section, late wood often appearing as a series of fine undulating concentric lines. Rays darker than surrounding tissue and prominent on a radial face; easily seen on end section.

*Microscopic characters.***—Tracheids very irregular in transverse section, usually irregularly rounded or polygonal; mean radial diameter, 50μ, max. 100μ, min. 25μ; length 2.6-8 mm., walls 3-10μ in thickness. Radial bordered pits in 1-4 rows or irregularly scattered, hexagonal to rounded, average diameter 14μ; tangential pits in one to three rows, numerous; pit openings rounded-oval to slit-like, about 6μ in length; pits usually alternate, occasionally opposite. Tracheid plugs numerous, but

* Welch, M. B. An examination of defective New Zealand Kauri (*Agathis australis*). Proc. Roy. Soc. N.S.W., lx, 1926.

† Kirk, T. The Forest Flora of New Zealand, Wellington, 1889, pp. 143-156.

** See also Garratt, G. A. Some New Zealand Woods—N.Z. State Forest Service, Professional Paper No. 1, 1924.

rarely more than 20μ in length. Rays uniseriate, 1-30 cells in height, cells thin walled, $15\text{-}40\mu$ in vertical height, up to 300μ in length; rays 2-5 per mm. of transverse section. Ray-tracheid pits semibordered, borders indistinct and often reduced to a very small margin; 1-11 per section of tracheid, but usually not exceeding 8, average diameter 8μ; pit openings large and rounded to slit-like, measuring up to 7μ in diameter. Marginal ray cells occasionally extended between tracheids producing elongated wood parenchyma cells with more or less dense granular contents. Ray cells usually with yellow-brown, almost clear, amorphous contents. Alkannin shows a large amount of oily or resinous material to be present in the ray cells and also in the wood parenchyma. Growth rings not pronounced, definitely thickened late wood often reduced to a single cell in width, junction of early and late often indistinct.

Aqueous extract turbid to very turbid, colourless, not opalescent, clears with alcohol, greenish-yellow with ferric chloride; bright clear yellow with caustic potash and lime water.

Burns usually with a smoky flame to a grey ash with a small amount of unburnt carbon.

Tracheid Plugs.—This term is used in preference to "resin plates" to describe the yellow-brown plugs commonly found in the tracheids adjacent to the medullary rays. These plugs are insoluble in cold or boiling alcohol, ether, acetone, petroleum ether, xylol or chloroform, whilst caustic potash even after boiling causes little alteration, except possibly some contraction and darkening in colour; in practically every case they are appreciably darkened, at times blackened by ferric chloride. They are unaffected by alkannin. In their behaviour they are identical with

certain of the contents found in the ray parenchyma cells, and in my opinion, in this genus, do not appear to consist of resin but of a phlobaphene substance. They resemble the alteration products found in many phloem parenchyma cells, which originally contained water soluble tannins. Baker and Smith (loc. cit.) were also of the opinion that these tracheidal plugs did not consist of resin, and described them as being a manganese compound; there is no evidence to disprove their statement. Although resinous bodies occur normally in the ray cells they are very rarely found in the tracheids. The formation of resin plates is well described by Record, who found them in a number of coniferous woods, as well as in certain Angiosperms*.

Vertical wood parenchyma has been noted in the secondary xylem of *A. microstachya* and *A. australis*, the wood appearing to be quite normal. It is hoped that it will be possible to deal with this more fully at a later date.†

Summary.—The individual identification of these woods does not appear to be an easy matter. The Queensland Kauris are usually lighter in weight and softer, whilst the nearest approach in physical and mechanical properties to New Zealand Kauri are those from Vanikoro and New Caledonia. Growth rings are not prominent in *A. microstachya* or in some specimens of *A. Palmerstoni*. Rays are often not prominent in *A. Palmerstoni*, otherwise they are usually pronounced in the various species.

Microscopically *A. australis* appears to differ in the almost simple pits occasionally present in the ray parenchyma and the indistinct borders, the nearest approach

* Record, S. J. Significance of Resinous Tracheids, Botanical Gazette, lxvi, 1918.

† These cells apparently occur as vertical extensions from the ray parenchyma, and according to Jeffrey (Anatomy of Woody Plants) cannot be regarded as true wood parenchyma.

to this being in *A. robusta.* Ray-tracheid semibordered pits are prominent in *A. lanceolata, A. microstachya* and *A. Palmerstoni.* Tracheid plugs were almost absent in the material examined of *A. Palmerstoni* and *A. microstachya,* and were especially prominent in *A. lanceolata, A. robusta, A. australis,* and to a lesser degree in *A. macrophylla,* the maximum size being observed in *A. robusta.* As suggested by Record (loc. cit.) the plugs would undoubtedly reduce the permeability of the wood and enhance its value, where they are present to a large degree, for vats, tubs and boat building.

The maximum length of tracheids was found in *A. lanceolata* and in *A. microstachya,* the measurement being in the vicinity of 9 mm. Radial bordered pits are in all cases multiseriate, ranging usually from 2-3 rows; a maximum of five rows was found in *A. lanceolata.* The pits are usually alternate but are frequently opposite; the openings are usually opposed. Tangential pitting is of frequent occurrence, and usually there is little difference in size between them and the radial pits. The average radial tracheid diameter is in the vicinity of 50-55μ. The thickness of the tracheid wall is usually from 3-5μ, a maximum of 10μ being observed in the late wood of the denser species, *A. lanceolata* and *A. australis.*

The rays are normally uniseriate, the greatest development of biseriate rays occurring in *A. macrophylla,* whilst no biseriate rays were found in *A. australis.*

The largest rays were found in *A. lanceolata* and *A. microstachya,* being up to about 40 cells in height, and the smallest in *A. Palmerstoni,* with 20 cells. The contents of the ray cells consist largely of insoluble phlobaphenes, though numerous starch grains are frequently present, even in the heart-wood; in some species also a considerable amount of resinous or oily bodies is present, especially in

A. australis, A. lanceolata, A. macrophylla, A. microstachya, and might have some effect on durability. The possible degree of variation of certain of the microscopical characters, due to variation in ecological conditions affecting the growth of the tree, necessitates that they should be used with caution.

The aqueous extract gave fairly constant results, and appears to be of some value for diagnosis. The turbidity of the solution obtained from *A. australis, A. lanceolata* and *A. macrophylla,* but especially in the former, is evidently due to the presence of oily or resinous bodies, whereas the Queensland Kauris gave clear solutions. In all material tried, the bright yellow colour obtained by the addition of caustic potash in the case of *A. australis,* was not approached by the other species. Both *A. Palmerstoni* and *A. microstachya* gave dark-coloured extracts, whilst that from *A. robusta* was pale yellow.

In conclusion, I am indebted to the timber merchants mentioned for certain of the material used, and to Mr. F. B. Shambler, of the Museum staff, for his assistance in preparing the test specimens and in other ways.

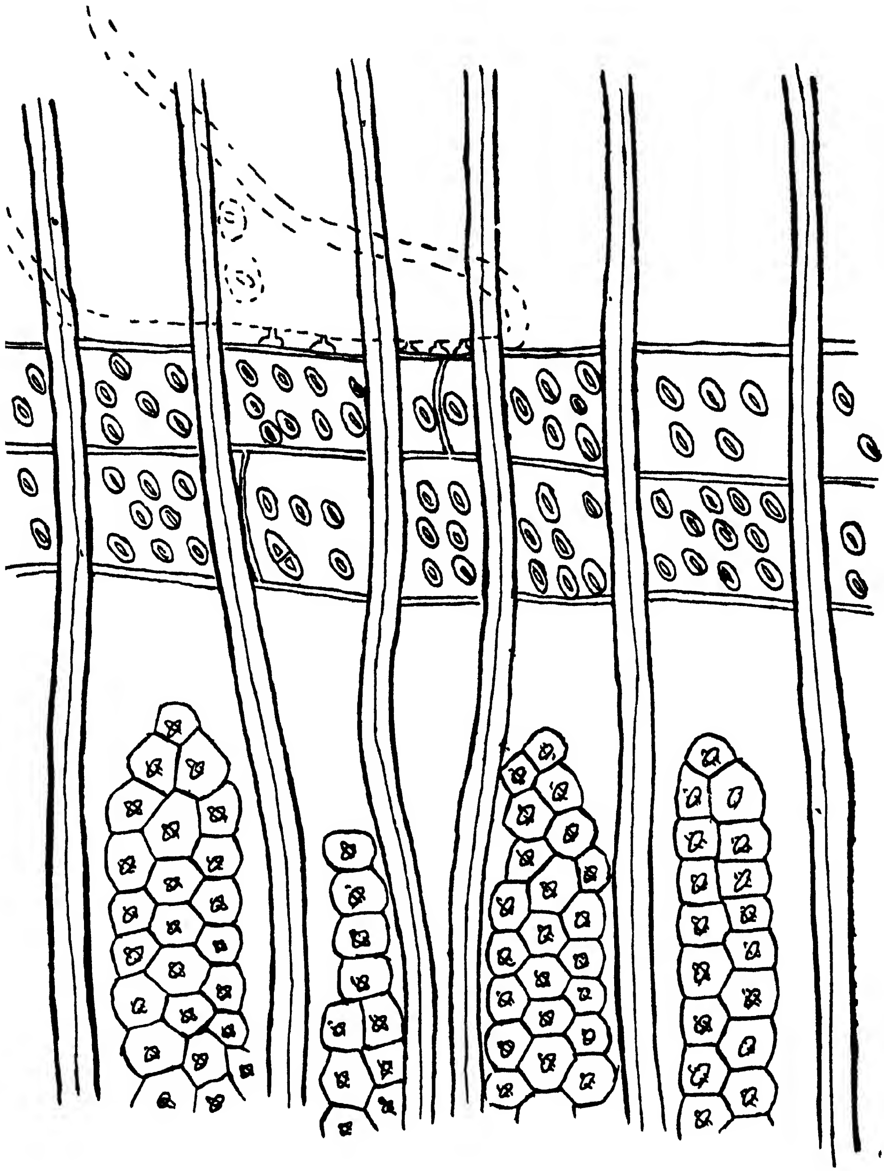

Fig. 1.

Radial section, *A. microstachya*, showing a narrow ray, two cells in height, and the distribution of the semi-bordered pits. The crowded radial bordered pits typical of the genus are seen in the tracheids below the ray, with the pit-openings opposed. Above is a tracheid end (dotted) in contact with the ray cells. × 400.

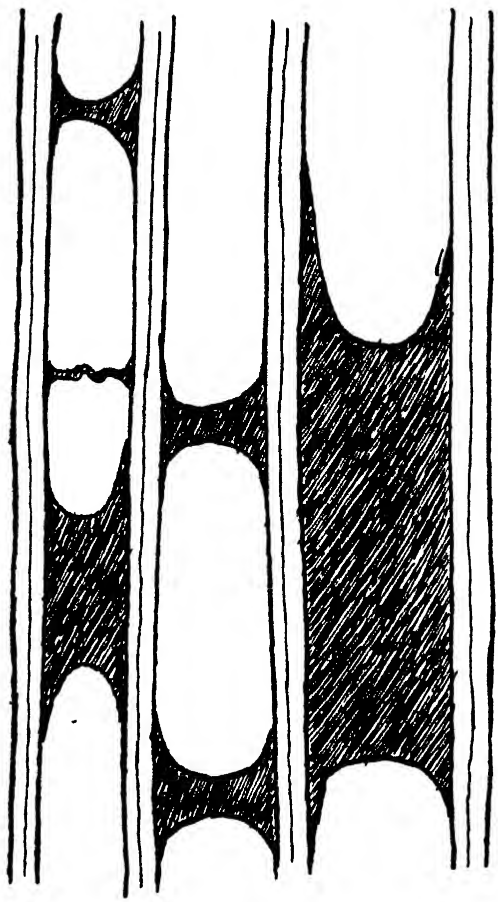

Fig. 2.
Radial view of portions of tracheids of *A. lanceolata*, showing tracheid plugs. × 300.

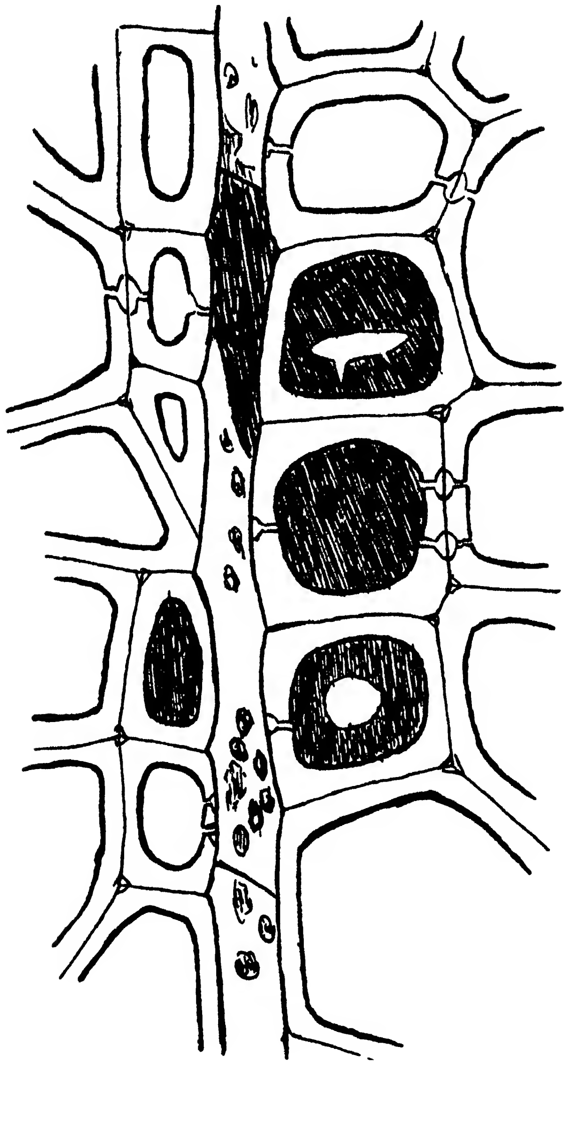

Fig. 3.

Transverse section of tracheids and ray of *A. macrophylla*, showing typical tracheid plugs. These do not always fill the cell cavity. In the adjoining ray parenchyma cell is similar phlobaphene material, oily or resinous bodies and starch granules. × 400.

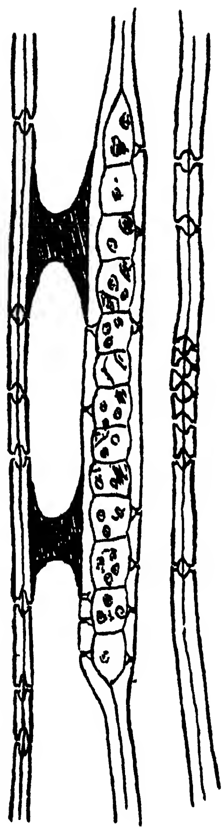

Fig. 4

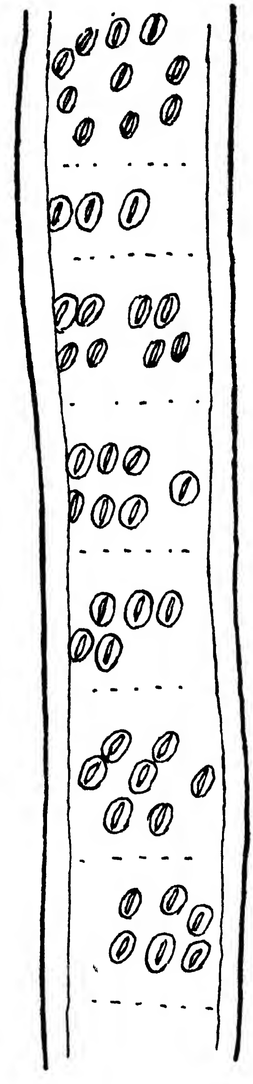

Fig 5

Fig. 4.

Tangential section of *A. lanceolata*, showing ray in section and two tracheid plugs in one of the adjacent tracheids. × 200.

Fig. 5.

Portion of isolated tracheid of *A. lanceolata*, showing distribution of ray-tracheid pits. × 400.

THE ESSENTIAL OILS OF *EUCALYPTUS MICRANTHA* (DE CANDOLLE) AND *E. HAEMASTOMA* (SMITH).

PART I.

By A. R. PENFOLD, F.A.C.I., F.C.S.,
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(With Plate VI).

(*Read before the Royal Society of N.S.Wales, 6th September, 1927.*)

In the course of the examination of various species of Eucalypts in the field, it was observed that the small fruited and narrow leaf form of *Eucalyptus haemastoma*, known as var. *micrantha,* could readily be distinguished from the type by the difference in odour of the essential oils when the leaves were crushed in the hand.

Messrs. Baker and Smith in the second edition of "Eucalypts and their Essential Oils" (1920) on page 247 described the essential oil of *E. haemastoma,* but beyond stating that when the fruits are small it is known as var. *micrantha* (Syn. *E. micrantha,* D.C.), and that De Candolle's species has been placed as a variety by Mueller, a classification in which they concurred, no further mention is made of this Eucalypt or its essential oil.

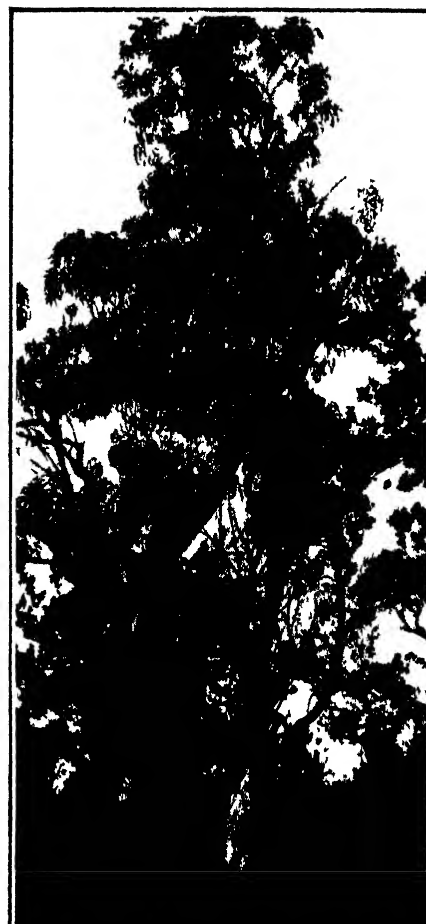
The field investigations led us to examine the essential oil, especially as the late J. H. Maiden, F.R.S., in his "Critical Revision of the Genus Eucalyptus", Volume 6, page 508, re-established the tree as a definite species.

The large quantity of phellandrene recorded as being present in the oil of *Eucalyptus haemastoma* appeared to be due to admixture of leaves of var. *micrantha* with those of the type, especially as Messrs. Baker and Smith considered the two to be identical except for the difference in size of the fruits. Even so, *E. micrantha* shows very distinct differences from *E. haemastoma,* especially regarding the leaves, which are quite broad and coriaceous in the case of *E. haemastoma,* whilst those of *E. micrantha* are narrow. No difficulty was experienced in selecting trees of the respective species in order to obtain material for oil distillation when they were found growing together.

It seemed advisable under the circumstances to examine the oils from trees of *E. haemastoma* growing on the Hawkesbury Sandstone at Hornsby district, close to Sydney, which, according to authorities, is the type locality. (See J. H. Maiden, "Critical Revision of the Genus Eucalyptus", Volume 6, page 505.) These oils were found to contain the terpene phellandrene, but the quantity was too small to be detected in the crude oils by the usual B.P. test. It was only in the course of the examination of the terpene fractions that its presence could be demonstrated. On the other hand the oil of *E. micrantha* contains this terpene in abundance. Moreover, the yields of oil differ considerably, being 0.3% in the case of *E. haemastoma* and 0.65 to 0.9% with *E. micrantha.*

We have examined many trees of each species in the field at Kuring-gai, Middle Harbour and National Park, where the two species grow close together. Although *E. haemastoma* shows considerable variation in size and shape of leaves, as well as in fruits, yet with care it is possible to readily distinguish the trees even when growing intermixed as at National Park. Usually *E. haemastoma* follows the sandstone ridges, whilst *E. micrantha* prefers better

Tree of *Eucalyptus haemastoma* at Kuring-gai, N.S.W.



Tree of *Eucalyptus micrantha* at Kuring-gai, N.S.W.

soil and is found a little further down the hillside, although not extending into the gullies, the line of demarcation being fairly well defined, but only in certain districts. We have observed them growing within a few feet of one another in fairly level situations close to water.

Photographs Nos. 1 and 2 are typical of *E. haemastoma* and *E. micrantha* respectively from Kuring-gai.

The essential oil of *E. haemastoma* is a thick viscous oil with a turpentine-like odour, whilst that of *E. micrantha* is a mobile oil with a pronounced odour of phellandrene, piperitol and sometimes aromatic aldehydes.

The results recorded in the paper refer only to oils obtained from trees growing within 30 miles of Sydney, with the single exception of one lot of material of *E. micrantha* from Hill Top, about 70 miles from Sydney, in the Southern District of New South Wales. This material was typical of *E. micrantha*, which has a more extended range than *E. haemastoma*, the fruits being very small and representative of the extreme type of this species. There appears to be, as one would naturally expect, a series of intermediate forms existing in the species *micrantha*, and some of the trees at Kuring-gai are of that nature. (For analogy see our paper read before the Royal Society of New South Wales on 1st June, 1927, entitled, "The occurrence of a number of varieties of *Eucalyptus dives* as determined by chemical analysis of the essential oils.")

We have examined the oils from trees growing at high altitudes, such as at Faulconbridge, Rydal, etc., in this State, and in this connection have not overlooked the species *Eucalyptus Rossii*. The results so far obtained do not warrant their discussion here, primarily on account of the differences of opinion that exist amongst botanists regarding this particular species. Discussion and publication of these results are, therefore, deferred for our

Part II. contribution. Similar remarks apply to our investigation of material from Brisbane, Queensland, which has also received much attention.

The Essential Oils.

EUCALYPTUS MICRANTHA (De Candolle).

The essential oils from the various consignments varied in colour from a bright yellow to reddish yellow, were fairly mobile and possessed a pleasant terpene odour modified by alcoholic and aldehydic constituents. In some, the trace of aromatic aldehydes of the cuminal-cryptal group was readily detected and lent a very pleasant and distinctive odour to a number of oils, especially those from Kuring-gai. A total of 599 lbs. weight of leaves and terminal branchlets was examined, of which 239 lbs. were obtained from the Sydney District.

The principal constituents which have so far been identified were found to be l-a-phellandrene, sesquiterpenes, terpineol? and piperitol and their caproic acid esters, d-a-pinene, cineol (under 10%), with sesquiterpene alcohols and traces of the aromatic aldehydes. Piperitone, if present, did not exceed 5% in quantity. Solid eudesmol, a characteristic and constant constituent of the oil of *E. haemastoma,* was found only in the oil obtained from Hill Top. The presence of this component is attributed to ecological conditions, as in a paper communicated to the Society in 1921 (Volume LV, pages 170-173), dealing with the essential oil of *Leptospermum flavescens,* it was shown that altitude had a considerable bearing upon the production of this solid sesquiterpene alcohol. The absence of eudesmol from the oil of coastal trees of *E. micrantha,* in our opinion, forms a characteristic distinction between that oil and that of *E. haemastoma.*

That variation exists in composition of the essential oils of individual trees was shown with the two trees at Kuring-

gai marked "A" and "B" as the former contained 33% cineol with a moderate quantity of phellandrene, pinene not detected, whilst the latter contained under 10% cineol, with a fair quantity of both pinene and phellandrene.

Experimental.

Five hundred and ninety-nine lbs. weight of leaves and terminal branchlets, yielded on distillation with steam crude oils, possessing the chemical and physical characters shown in table:—

Lot, 21/7/1924.

100 cc. crude oil on distillation at 10 mm. gave the following results:—

1st drops 50°.

Fraction.	Volume.	$d\frac{15}{15}$	α_D^{20}	n_D^{20}
50-65°	48 cc.	0.8605	− 33.7°	1.4759
66-85°	18 cc.	0.8693	− 31°	1.4780
86-112°	9 cc.	0.9077	− 25.3°	1.4831
above 112°	25 cc.	0.920	± 0°	1.5070

Lot, 27/10/1925. *Sample "A".*

100 cc. crude oil on distillation at 10 mm. gave the following results:—

Fraction.	Volume.	$d\frac{15}{15}$	α_D^{20}	n_D^{20}	Cineol.
50-65°	68 cc.	0.8934	− 26.5°	1.4653	48%
65-85°	18 cc.	0.9056	− 7.2°	1.4681	—
Residue	14 cc.	—	—	—	—

Lot, 27/10/1925. *Sample "B".*

100 cc. crude oil on distillation at 10 mm. gave the following results:—

Fraction.	Volume.	$d\frac{15}{15}$	α_D^{20}	n_D^{20}
50-65°	46 cc.	0.8632	+ 5.65°	1.4762
75-100°	10 cc.	0.8875	− 8.9°	1.4820
100-135°	20 cc.	0.9529	− 2.5°	1.5002

EUCALYPTUS MICRANTHA (De Candolle)

Date	Locality	Weight of Leaves	Yield of Oil. %	$d\frac{15}{15}$	α_D^{20}	n_D^{20}	Solubility in 80% Alcohol.	Ester No 1½ hours hot sap.	Ester No after Acetylation	Cineol Content	Phellandrene.	Remarks
21/7/24	Kuring-gai	82lbs.	0.64	0.8926	−25.5°	1.4843	5 vols.	13.2	60.8	about 10%	Large quantity present	
27/10/25	,, ,,	50½ ,,	0.9	0.9051	− 3.1°	1.4701	6 vols. (70% alcohol)	6.2	41.9	33%	Moderate quantity present	Tree "A"
,,	,, ,,	50½ ,,	0.65	0.9122	+ 5°	1.4892	1 vol.	12.8	86.7	under 10%	,,	Tree "B"
4/12/25	,, ,,	26 ,,	0.62	0.8883	−17°	1.4865	8 vols.	23.1	80.3	,,	,,	
14/12/25	Waterfall	20 ,,	0.67	0.9006	−15.2°	1.4877	4 vols.	18.4	93.7	,,	,,	
2/9/26	Hill Top N.S.W	370 ,,	0.76	0.9033	−19.5°	1.4890	1.2 vols.	16.1	95.2	about 10%	Large quantity present	Very small fruit

Lot, 2/9/1926. Hill Top.

300 cc. crude oil on distillation at 10 mm. gave the following results:—

Fraction.	Volume.	$d\frac{15}{15}$	α^{20}_{D}	n^{20}_{D}
Up to 65°	140 cc.	0.8584	− 44.75°	1.4782
65-80°	30 cc.	0.8777	− 32.2°	1.4805
80-120°	20 cc.	0.9214	− 16.4°	1.4872
120-155°	56 cc.	0.9500	+ 19.40°	1.5010
155-160°	25 cc.	0.9712	+ 22.0°	1.5085
Residue	29 cc.	—	—	—

Determination of l-a-Phellandrene and Cineol.—The fraction boiling at 50-65°, 48 cc. ex. lot, 21/7/1924, was found to contain a small quantity of cineol, about 8%, and this was removed by means of 50% resorcin solution. The cineol-free terpene was repeatedly distilled over metallic sodium when it boiled at 58-60° at 10 mm., and possessed the following constants:—

$$d\frac{15}{15},\ 0.8502,\ \alpha^{20}_{D},\ -37.8°,\ n^{20}_{D},\ 1.4777.$$

It gave a good yield of nitrosite, melting at 113°.

The first fraction, B Pt. up to 65° at 10 mm. 140 cc. ex. Hill Top, consignment 2/9/1926, was found to contain about 18% of cineol, soluble in 50% resorcin solution. After its removal the phellandrene fraction distilled at 59-60° at 10 mm. and had

$$d\frac{15}{15},\ 0.850,\ ,\ \alpha^{20}_{D},\ -50°,\ n^{20}_{D},\ 1.4765$$

It yielded a nitrosite, after purification from acetone, melting at 113°. 0.4832 gram in 10 cc. chloroform gave a reading of

$$+\ 5.5°,\ [\alpha]^{20}_{D},\ +\ 114°$$

Determination of Phenol, alcohols and esters.—500 cc. crude oil on treatment with 8% sodium hydroxide solution yielded only 0.25 gram crude phenol, which gave an indefinite dirty-brown colour reaction with ferric chloride in alcoholic solution.

The oil after removal of phenolic constituents was treated with alcoholic potassium hydroxide solution at room temperature to remove esters. The ester free oil was subjected to steam distillation to remove the greater portion of the phellandrene, and the residual oil separated and distilled at 10 mm. with the following results:—

Boiling Point	Volume.	$d\frac{15}{15}$	α_D^{20}	n_D^{20}
65-87 (7 mm.)	16 cc.	0.8799	$-29°$	1.4793
87-100 (7 mm.)	18 cc	0.9096	$-20°$	1.4825
100-132 (7 mm.)	17 cc.	0.9298	$-4°$	1 4941
132-160 (7 mm.)	17 cc.	0.9627	$+20\ 4°$	1.5072

The fraction distilling at 87-100° at 7 mm. 18 cc. on oxidation with chromic acid solution yielded some piperitone, which was purified by means of neutral sulphite solution. The purified ketone possessed all the chemical and physical characters associated with this substance when isolated from Eucalyptus oils. The principal alcohol concentrated in this fraction, both free and as caproate, is piperitol. Other alcohols such as terpineol are undoubtedly present, but insufficient quantities of oil were available to enable their isolation and definite identification to be effected.

Determination of Acids present as Esters.—The alkaline liquors resulting from the saponification were acidified with dilute sulphuric acid solution and steam distilled. The distillate contained a small quantity of oily acid, which was separated from the aqueous portion. Both the aqueous and oily volatile acids were neutralised with ammonia solution, and the silver salts prepared therefrom. The silver salts on ignition gave the following results:—

Aqueous Acid.—0.0696 gram silver salt gave 0.0338 gram silver = 48.6% Ag.

Oily Acid.—0.0694 gram silver salt gave 0.0334 gram silver = 48.1% Ag. The silver salt of caproic acid requires 48.43% Ag.

Determination of Eudesmol.—The high boiling fractions from Hill Top, 2/9/1926, consignment all solidified on standing 24 hours.

They were transferred to porous tiles for the removal of adhering sesquiterpenes, and the white solid recrystallised from ethyl alcohol and water. The crystals melted at 79-80°.

1.0760 gram in 10 cc. chloroform gave a reading of +3.6.

$$[\alpha]_D^{20} = +33.4°$$

EUCALYPTUS HAEMASTOMA (Smith).

Leaves and terminal branchlets for comparative purposes were collected at the same time and place as that of *E. micrantha,* a total of 367-lbs. weight in all.

On distillation with steam, brownish yellow viscous oils were obtained in a yield of 0.3 to 0.5%. The principal constituents were found to be eudesmol, sesquiterpenes (aromadendrene and probably eudesmene), d-α-pinene, cineol (10-15%) with a very small quantity of phellandrene.

The oils from Kuring-gai when first distilled solidified, but after keeping for some time, probably due to repeated melting in the course of their examination, remained in the liquid condition.

The presence of solid eudesmol in the coastal material and the non-detection of phellandrene in the crude oils by the B.P. test offer a ready means of distinguishing the oil from that of *E. micrantha.*

EUCALYPTUS HAEMASTOMA (Smith).

Date	Locality.	Weight of Leaves	Yield of Oil. %	$d\frac{15}{15}$	a^{20}_{D}	n^{20}_{D}	Solubility in 70% Alcohol.	Ester No. 1½ hours hot sap.	Ester No after Acetylation.	Cineol Content.	Phellandrene. B.P. Test.	Remarks
21/7/24	Kuring-gai, N.S.W.	90lbs	0.32	0.9525	+16.8°	1.4931	1.8 vols.	8.9	116.0	about 10%	Not detected	Oil solidified soon after distillation
31/7/25	Sutherland, near Sydney	171 ,,	0.31	0.9295	+3.3°	1.4861	1.0 vol. (80% alcohol)	11.6	72.5	13%	,,	Laevo-rotatory sesquiterpene present
19/10/25	Middle Harbour	19 ,,	0.5	0.9494	+10.4°	1.4906	1.9 vol.	12.0	116.9	10/15%	,,	Tree "A" leaves much narrower than Tree "B"
,,	,,	37 ,,	0.5	0.9571	+14.8°	1.4957	2.0 vols.					
27/10/25	Kuring-gai	50 ,,	0.25	0.9552	+15.5°	1.4943	1.7 vols.	8.6	111.6	,,	,,	

Experimental.

Three hundred and sixty-seven lbs. weight of leaves and terminal branchlets yielded, on distillation with steam, crude oils possessing the chemical and physical characters shown in table:—

Lot, 23/7/1924.

100 cc. crude oil, on distillation at 10 mm., behaved as follows:—

Fraction.	Volume.	$d\frac{15}{15}$	α_D^{20}	n_D^{20}	Cineol.
50-65°	18 cc	0.8939	+12.85°	1.4640	53%
65-100°	8 cc.	0.9128	+7.15°	1.4709	—
100-150°	13 cc.	0.9619	+13°	1.5020	—
150-160°	balance	0.9731	+19.2°	1.5061	—

Lot, 31/7/1925.

100 cc. crude oil, on distillation at 10 mm., gave the following results:—

Fraction.	Volume.	$d\frac{15}{15}$	α_D^{20}	n_D^{20}	Cineol.
50-65°	25 cc.	0.870	+8.55°	1.4659	55%
65-98°	18 cc.	0.903	+5°	1.4660	—
98-138°	20 cc.	0.9384	±0°	1.4969	—
138-150°	30 cc.	0.9572	−1.4°	1.5035	—
Residue	7 cc.	—	—	—	—

Determination of d-a-Pinene.—The first fraction of boiling point 50-65° at 10 mm., 23/7/1924 lot, was treated with 50% resorcin solution for the removal of cineol. The remaining terpene was distilled over metallic sodium, when it was found to distil at 150-159° at 765 mm., and to possess the following physical characters:—

$d\frac{15}{15}$, 0.8625, α_D^{20}, +23.2°, and n_D^{20}, 1.4681°

On mixing with one-third of its volume of l-α-pinene α_D^{20} −50°, it gave an excellent yield of nitrosochloride, melting with decomposition at 109°.

The pinene fractions from lot, 31/7/1925, were found to distil at 160-168° at 765 mm., and to have:

$d\frac{15}{15}$, 0.8682, α_D^{20}, + 15°, and n_D^{20}, 1.4672.

The presence of pinene was confirmed by the preparation of the nitrosochloride, and phellandrene was detected in very small quantity by the nitrosite reaction. β-pinene was proved to be absent.

Determination of Cineol.—The resorcin washings from the pinene fractions were subjected to steam distillation, and the regenerated cineol collected and purified by distillation over sodium. It distilled at 175-177 at 763 mm. and had:

$$d\frac{15}{15},\ 0.929,\ \alpha^{20}_{D},\ -0.2^\circ,\ \text{and}\ n^{20}_{D},\ 1.458.$$

It reacted with phosphoric acid in the usual manner, and gave the iodol derivative melting at 112°.

Determination of Eudesmol.—The fourth fraction, 23/7/1924, which solidified soon after the constants were taken, was pressed on a porous tile to remove adhering sesquiterpenes. On purification from ethyl alcohol and water it melted at 80°. 1.3366 grs. in 10 cc. chloroform gave a reading of $+4.65^\circ$ $[\alpha]^{20}_{D}$ $+34.79^\circ$.

The Sesquiterpenes.—The sesquiterpenes usually present in Eucalyptus oils were detected, but on account of the large quantity of eudesmol present it was impossible to isolate them in a condition of purity. They were present in greatest quantity in the oil, 31/7/1925, and, possessing a laevo-rotation, neutralised the dextro rotation of the sesquiterpene alcohol.

In conclusion, we wish to express our indebtedness to Mr. E. Cheel, Curator of the National Herbarium, Sydney, for his usual kindly criticism and interest in investigations of this nature. Our best thanks are also due to Mr. D. E. Chalker, of Hill Top, for his invaluable assistance in furnishing such an excellent supply of the leaves of *E. micrantha.*

THE VERTICAL GROWTH OF TREES. No. II.

By R. H. CAMBAGE, C.B.E., F.L.S.

(*Read before the Royal Society of N.S. Wales, October 5, 1927.*)

In a paper read before this Society in 1918, I discussed the question of the vertical growth of trees, and the conclusion then arrived at was that once a young tree throws out definite branches, the portion of the stem below such branches will increase in diameter but not appreciably in length, and nails placed in the stem at any vertical distance apart will retain their positions, relatively to each other, for at least several years, irrespective of how high the tree may grow.*

During the succeeding nine years the investigations have been continued, the system adopted being to place small nails, one foot apart, in the stems of young trees, measurements being made from time to time between the nails, starting from the lowest or base nail. In these further experiments, made chiefly with trees of the genus *Eucalyptus*, nothing has been found to modify the views expressed above.

Among the examples quoted in the present paper it may be noticed that a young tree of *Eucalyptus paniculata* (Grey Ironbark), had nails placed in it one foot apart up to a height of eleven feet, when the total height of the

* This Journal, 1918, 52, 377.

tree was sixteen feet. In three years the tree had increased its height by 44%, and had reached twenty-three feet, but the nails remained one foot apart, and the nail marking the eleventh foot was still eleven feet from the base nail. At the end of five years the tree had increased its original height by 56%, and had reached twenty-five feet, but the highest nail was still practically eleven feet from the base nail.

An *Acacia* sp. grew in one year from five feet nine inches to fifteen feet, an increase of 160%, yet a nail placed at four feet from the base remained in the same position during the whole year, although the tree was growing rapidly.

The results of these further observations go to show that the extension of the stem is made at the summit or growing-point of the plant, and not between the branches.

It is difficult always to guarantee the accuracy of the measurements on the upper portion of the tree nearer than to about half an inch. Where the tree grows perfectly straight and there are no branches in the way, a high degree of accuracy can be maintained.

In the following tables the first column indicates the positions of nails, one foot apart, driven into the stem on a given date, and also the number of branches between consecutive nails. The remaining columns show the measurements to each nail on subsequent dates, and the number of branches then remaining, there being practically no difference found in the position of the nails in the great majority of cases. The columns also show where higher nails have been placed as the stems increased in height.

The diameter of the stem was measured at two feet from the ground in all cases.

Acacia pycnantha Benth.

27/5/1916 Diam. ½ in. Height 6 ft.	28/7/1918 Diam. 3½ in. Height 16 ft.	6/6/1920 Diam. 5½ in. Height 20 ft.
	9 feet	9 feet
	6 brans.	6 brans.
	8 feet	8 feet
	4 brans.	3 brans.
	7 feet	7 feet
	4 brans.	4 brans.
	6 feet	6 feet
	6 brans.	no bran.
	5 feet	5 feet
	5 brans.	1 bran.
4 feet	4 feet	4 feet
6 brans.	5 brans.	8 brans.
3 feet	3 feet	3 feet
1 bran.	4 brans.	3 brans.
2 feet	2 feet	2 feet
3 brans.	no bran.	no bran.
1 foot	1 foot	1 foot
1 bran.	1 bran.	1 bran.
Ground		

Angophora lanceolata Cav.

17/8/1918 Diam. 1½ in. Height 10 ft.	15/11/1919 Diam. 2½ in. Height 14 ft
-	
7 feet	7 feet
5 branches	3 branches
6 feet	6 feet
8 branches	7 branches
5 feet	5 feet
7 branches	5 branches
4 feet	4 feet
5 branches	8 branches
3 feet	3 feet
2 branches	no branch
2 feet	2 feet
7 branches	5 branches
1 foot	1 foot
2 branches	1 branch
Ground	

Eucalyptus corymbosa Sm.

17/8/1918 Diam, 2½ in Height 15 ft	15/11/1919 Diam. 3½ in. Height 18 ft.
10 feet	10 feet
6 branches	5 branches
9 feet	9 feet
1 branch	no branch
8 feet	8 feet
5 branches	4 branches
7 feet	7 feet
7 branches	2 branches
6 feet	6 feet
1 branch	1 branch
5 feet	5 feet
7 branches	5 branches
4 feet	4 feet
no branch	no branch
3 feet	3 feet
1 branch	1 branch
2 feet	2 feet
2 branches	2 branches
1 foot	1 foot
no branch	no branch
Ground	

Eucalyptus Sieberiana F. v. M.

12/2/1922 Diam. 1½ in. Height 14 ft	21/5/1927 Diam. 2½ in, Height 18½ ft
10 feet	10feet
2 branches	no branch
9 feet	9 feet
2 branches	1 branch
8 feet	8 feet
2 branches	1 branch
7 feet	7 feet
3 branches	no branch
6 feet	6 feet
1 branch	1 branch
5 feet	5 feet
1 branch	3 branches
4 feet	4 feet
no branch	no branch
3 feet	3 feet
no branch	no branch
2 feet	2 feet
no branch	3 branches
1 foot	1 foot
no branch	no branch
Ground	

Eucalyptus paniculata Sm.

4/8/1922 Diam. 2¾ in. Height 16 ft	12/7/1925 Diam. 4¼ in Height 23 ft.	24/9/1927 Diam. 5 in. Height 25 ft.
11 feet	11 feet	10 ft. 11⅝ in
8 brans.	2 brans	2 brans.
10 feet	10 feet	9 ft. 11¾ in
5 brans.	4 brans.	3 brans.
9 feet	9 feet	8 ft. 11¾ in
4 brans.	2 brans.	1 bran.
8 feet	8 feet	8 feet
2 brans.	no bran.	no bran.
7 feet	7 feet	7 feet
8 brans.	no bran.	no bran.
6 feet	6 feet	6 feet
1 bran.	1 bran.	no bran.
5 feet	5 feet	5 feet
8 brans.	no bran	no bran.
4 feet	4 feet	4 feet
1 bran.	no bran.	no bran.
3 feet	3 feet	3 feet
2 brans.	no bran	no bran.
2 feet	2 feet	2 feet
3 brans.	no bran.	no bran.
1 foot	1 foot	1 foot
3 brans.	no bran	no bran.
Ground		

Eucalyptus acmenioides Schauer.

4/8/1922 Diam. 2¼ in. Height 10 ft.	12/7/1925 Diam. 3¼ in. Height 14 ft	24/9/1927 Diam. 3¾ in. Height 15 ft.
8 feet	8 feet	8 feet
6 brans.	1 bran.	1 bran.
7 feet	7 feet	7 feet
4 brans.	3 brans.	3 brans
6 feet	6 feet	6 feet
5 brans.	4 brans.	3 brans.
5 feet	5 feet	5 feet
3 brans.	2 brans.	1 bran.
4 feet	4 feet	4 feet
3 brans.	1 bran.	no bran.
3 feet	3 feet	3 feet
4 brans.	1 bran.	1 bran.
2 feet	2 feet	2 feet
2 brans	no bran.	no bran.
1 foot	1 foot	1 foot
6 brans.	no bran	no bran.
Ground		

Eucalyptus saligna Sm.

4/3/1922 Diam. 3 in. Height 16 ft	12/7/1925 Diam 3¾ in Height 22 ft.	24/9/1927 Diam. 4¼ in Height 24 ft
	12 feet	11 ft. 11¼ in
	1 bran.	1 bran
11 feet	11 feet	10 ft 11¾ in
3 brans.	1 bran.	no bran.
10 feet	10 feet	9 ft. 11¾ in
1 bran.	no bran.	no bran.
9 feet	9 feet	9 feet
no bran.	no bran.	no bran.
8 feet	8 feet	8 feet
3 bran.	no bran.	no bran.
7 feet	7 feet	7 feet
4 brans.	no bran.	no bran.
6 feet	6 feet	6 feet
6 brans.	no bran.	no bran.
5 feet	5 feet	5 feet
5 brans.	no bran.	no bran.
4 feet	4 feet	4 feet
3 brans.	no bran.	no bran.
3 feet	3 feet	3 feet
3 brans.	no bran.	no bran.
2 feet	2 feet	2 feet
3 brans	no bran.	no bran
1 foot	1 foot	1 foot
2 brans.	no bran.	no bran.
Ground		

Eucalyptus resinifera Sm.

4/3/1922 Diam. 3 in. Height 14 ft.	12/7/1925 Diam 4 in. Height 18 ft	24/9/1927 Diam. 4½ in. Height 20 ft.
11 feet	11 feet	10 ft 11¾ in
5 brans.	2 brans.	1 bran.
10 feet	10 feet	9 ft. 11¾ in
8 brans.	2 brans.	1 bran.
9 feet	9 feet	9 feet
5 brans	2 brans.	1 bran.
8 feet	8 feet	8 feet
8 brans.	1 bran.	1 bran.
7 feet	7 feet	7 feet
3 brans.	2 bran.	2 brans.
6 feet	6 feet	6 feet
2 brans.	no bran	no bran.
5 feet	5 feet	5 feet
4 brans	no bran.	no bran.
4 feet	4 feet	4 feet
3 brans.	no bran.	no bran.
3 feet	3 feet	3 feet
5 brans.	no bran.	no bran.
2 feet	2 feet	2 feet
2 brans.	no bran.	no bran.
1 foot	1 foot	1 foot
1 bran.	no bran.	no bran.
Ground		

Grevillea robusta A. Cunn.			*Acacia mollissima* Willd. var.	
4/5/1922 Diam. 5¼ in. Height 24 ft.	12/7/1925 Diam. 8¾ in. Height 31 ft.	24/9/1927 Diam. 10 in. Height 33 ft	21/8/1926 Diameter ¾ in. Height 5 ft. 9 in.	6/4/1927 Diameter 1¾ in. Height 15 ft.
11 feet	11 feet	11 ft. ¼ in.		11 feet
10 brans	1 branch	1 branch		3 branches
10 feet	10 feet	10 ft. ¼ in.		10 feet
6 brans	3 brans	4 brans.		3 branches.
9 feet	9 feet	9 ft. ¼ in.		9 feet
6 brans.	4 brans.	3 brans.		4 branches.
8 feet	8 feet	8 feet		8 feet
7 brans	no bran	2 brans		6 branches
7 feet	7 feet	7 feet		7 feet
7 brans	2 brans.	no bran.		6 branches.
6 feet	6 feet	6 feet		6 feet
8 brans	no bran	no bran.		2 branches.
5 feet	5 feet	5 feet		5 feet
8 brans.	no bran.	no bran		4 branches.
4 feet	4 feet	4 feet	4 feet	4 feet
7 brans.	no bran	no bran.	7 branches.	7 branches.
3 feet	3 feet	3 feet	3 feet	3 feet
no bran	no bran.	no bran	9 branches.	8 branches.
2 feet	2 feet	2 feet	2 feet	2 feet
no bran	no bran.	no bran.	3 branches	2 branches.
1 foot	1 foot	1 foot	1 foot	1 foot
no bran.	no bran	no bran	4 branches	no branch.
Ground			Ground	

From the foregoing tests it will be seen that the vertical growth in young trees appears to be limited practically to the terminal shoot or growing-point, and probably to some inches below, but does not extend to the lower portion of the stem among the branches.

Instances are often noticed where a growing tree has been morticed and used as a fence post. In such cases the rail has been seen to remain horizontal even after twenty years, though the new wood may be growing over it from the tree for several inches.

Where a branch grows out in an approximately horizontal position, it follows that as it increases in diameter the upper surface will increase in height to the extent of half the increase in diameter of the branch, and the under surface of the branch will become lower to the same extent. If a branch should grow at an angle of 45 degrees with a

vertical tree trunk, then the upper angle or fork will be carried upwards in response to the increase of both trunk and branch diameter; and if the diameter increase of the trunk should be two feet, and that of the branch one foot, the fork will be carried upwards approximately one foot eight and a half inches.

The smaller the angle that the branch makes with the trunk, the more is the fork carried upwards as the trunk and branch increase in diameter.

It is well known that many *Eucalyptus* trees may be seen with clean limbless boles up to a height of fifty feet, and the explanation of this lies in the fact that where trees grow in sheltered situations and are closely packed among many neighbours, they run up rapidly in their upward search for the light, and during this process the young boles produce many branches which never mature, but, when little more than twigs, die and practically fall out of the tree. In this way the trunk becomes naturally disbranched, sometimes up to a great height. The foregoing tests give examples of the gradual decrease in the number of branches as the trees grow.

These tests furnish no conclusive criterea as to the rate of growth of *Eucalyptus* trees, for the particular examples used are growing among large trees, ranging from fifty to eighty feet high, which have first call on the nutriment in the soil.

THE ESSENTIAL OILS OF TWO SPECIES OF *BAECKEA*.

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(*Read before the Royal Society of New South Wales, Nov. 2, 1927.*)

Baeckea brevifolia (De Candolle).

The botany of this small Myrtaceous shrub is fully described in Bentham's "Flora Australiensis," Vol. III., page 78. It is a very low growing plant, with thick three-sided leaves under ¼in. long, and apparently does not exceed 18in. in height. It is said to occur in the Port Jackson District and the Blue Mountains of New South Wales, but the author is only acquainted with it from the latter district.

The Essential Oils.

Material for essential oil purposes has been collected from one locality only, viz., Faulconbridge, on the Blue Mountains, where it occurs in a swampy depression close to the railway station. The plant is too small and sparsely distributed to be of any economic value but, in a botanico-chemical study of Myrtaceous plants yielding essential oil, it could not be overlooked, especially as it covered prac-

tically the whole of the limited area from which it was collected. Altogether, 212lbs. weight of leaves and terminal branchlets were collected, one lot in August, 1925, a fair average season, and the second lot in September, 1927, after a spell of very dry weather extending over six months, when the swampy nature of its habitat could not be recognised. The plant was very dry and gradually dying off. The yield of oil, therefore, was much lower than from the first lot, 1% as against 1.6%, whilst the eudesmol content was much higher. It is truly remarkable that a plant, possessing such an extremely small leaf, should contain so much essential oil.

The oil is of special scientific interest on account of the large quantity of β-pinene and eudesmol (30-45%) present.

The principal constituents which have so far been identified are:—α- and β-pinene, the latter predominating, cineol, and eudesmol, with small quantities of phenolic constituents.

Experimental.

The Essential Oils were obtained by steam distillation. The first portion of the distillate was a very pale greenish yellow mobile liquid of terpenic odour, whilst the second portion came over as a brownish white solid. These were kept separate, and portions only of each mixed to obtain a representative sample of crude oil which, at room temperature, 20-25°, was a solid.

The chemical and physical characters of each portion are recorded separately on account of their exceptional technical interest.

The crude oils possessed the physical and chemical characters, shown in the accompanying table:—

Date.	Locality	Weight of Leaves	Yield of Oil %	$d\frac{15}{15}$	α^{20}_{D}	n^{20}_{D}	Solubility in Alcohol	Ester No 1½ hours hot.	Ester No after Acetylation.	Remarks.
7/8/25	Faulconbridge Blue Mts., N.S.W.	161lbs	1.6	0.9110	−3.9°	1.4839	Insol. 10 vols. 70%. Soluble 0.6 vols 80%	3.2	75	800 grms. Oil, 360 grms. Solid. Oil solidified at room temperature.
15/9/27	do.	51lbs	1.02	0.9257	too dark to read	1.4888	do.	5.4	109	170 grms Oil, 68 grms Solid. Oil solidified at room temperature,

The distillates were first obtained in separate fractions, the eudesmol distilling over as a solid towards the end, consequently it was deemed advisable to record the chemical and physical characters of each, separately.

Liquid portion, 1925 lot	0.8927	−13°	1.4762	Insol. 10 vols. (70% alcohol).	1	42.5	
Liquid portion, 1927 lot	0.9077	−8.2°	1.4822	Insol 10 vols. (70% alcohol)	5.4	78.7	
Solid portion, 1925 lot	0.9533 $\left(\frac{27.5}{15}\right)$	+18°	1.5010	Soluble in 1.7 vols (70% alcohol)	7.8	142	M pt. 52°

400 c.c. of crude oil (1st fraction) on distillation yielded 80% boiling below 75° at 20 mm., 5% boiling between 75° at 20 mm. and 120° at 10 mm., and 13% at 120-155° at 10 mm.

Determination of a and β Pinene.

100 c.c. of the fraction distilling below 75° at 20 m.m. were shaken with 50% resorcin solution for the removal of cineol. 84 c.c. of terpene were thus returned, and on fractional distillation over metallic sodium at 760 m.m, using a four-pear column, yielded the following fractions:

B.pt.	Volume	$d\frac{15}{15}$	a^{20}_D	n^{20}_D
158-160	20 c.c.	0.8684	-21°.35	1.4703
160-166	56 c.c.	0.8698	-20°.3	1.4716

a Pinene.

Both fractions on treatment with amyl nitrite in hydrochloric-acetic acid solution yielded the characteristic nitrosochloride of a pinene which, after purification, melted with decomposition at 115°.

β Pinene.

Both fractions were oxidised with potassium permanganate in the presence of sodium hydroxide (see Volume LIV. (1920), page 204), when an excellent yield of crystals of sodium nopinate was obtained, especially from the second fraction. These crystals, on treatment with dilute sulphuric acid, yielded nopinic acid which, when recrystallised from benzene, melted at 127°. The terpenes, therefore, consisted almost entirely of a and β pinene, the latter preponderating.

Determination of Cineol.

On passing a rapid current of steam through the resorcin washings from the terpenes, a water white liquid of camphoraceous odour distilled over. On distillation over

metallic sodium, it boiled at 173-175° (uncorr.) at 762 m.m. and possessed the following constants:—
d_{15}^{15}, 0.9281; α_D^{20}, +0.25°; n_D^{20}, 1.4575; congealing point -3°. Its identity with cineol was confirmed by its reaction with phosphoric acid and the formation of characteristic iodol compound, M. pt. 112°.

Determination of Eudesmol and Sesquiterpene.

The fraction distilling at 120-150°, 50 c.c., soon partially solidified and the buttery mass was transferred to a porous plate for the removal of adhering sesquiterpenes. These could not, of course, be separated for identification, but their presence was proved by the usual colour reactions for these components of Australian essential oils of the N.O. Myrtaceæ.

The solid remaining on porous plate was recrystallised from ethyl alcohol and water, when the crystals melted at 80.5-81°, 1.4994 gram, in 10 c.c. chloroform, gave a reading of +3.8, $[\alpha]_D^{20}$, +25.3.

100 grs. of the 2nd fraction (crude oil), which was a solid of M. pt. 52° were taken, dissolved in ether, and the phenolic constituents removed by washing with 8% sodium hydroxide solution. After removal of ether, the white solid distilled at 155-157° at 10 m.m. and melted at 80.5-81°.

1.3552 gram in 10 c.c. chloroform gave a reading of +3.25°.

$$[\alpha]_D^{20} = +24°.$$

The two lots of crystals possessed the usual characteristic physical properties of eudesmol and each, with cyanic acid, yielded an allophanate melting at 174°. This is the first time that an additive derivative of this sesquiterpene alcohol has been prepared.

Phenolic Constituents.

The sodium hydroxide washings from the eudesmol fraction on treatment with dilute sulphuric acid yielded 0.36 gram of a crude liquid phenol which gave a dark brownish red colouration with ferric chloride in alcoholic solution, but could not be identified.

BAECKEA LINIFOLIA var. BREVIFOLIA (Mueller)*.

The botany of this shrub is likewise fully described in Bentham's "Flora Australiensis," Volume III., page 80. It is a tall erect shrub, with nearly cylindrical dark green leaves, small white flowers, and drooping branches. It is fairly plentiful in the coast districts and Dividing Range of New South Wales, extending into Victoria, where it is found following the creeks and water courses, showing a preference for rocky clefts. It is of no economic value, but its examination was necessary for the reasons set forth under *B. brevifolia.*

The Essential Oils.

The Essential Oils varied from a pale yellow to brownish yellow in colour, were quite mobile and possessed a pleasant terpenic odour.

The principal constituents which have so far been identified are:—α and β Pinene, cymene, cineol (18%) sesquiterpene and sesquiterpene alcohol, together with unidentified are:—α and β pinene, cymene, cineol (18%) phenolic constituent belonging to the Tasmanol-Leptospermol series.

Experimental.

179-lbs. weight of leaves and terminal branchlets from the various New South Wales localities enumerated,

* Bentham has pointed out that this species is probably identical with *Baeckea leptocaulis* of Tasmania, and Mr. E. Cheel, Curator of the National Herbarium, Sydney, is of the same opinion.

yielded on distillation with steam the following crude oils, possessing the chemical and physical characters shown in the accompanying table:—

BAECKEA LINIFOLIA var. *BREVIFOLIA* (Mueller).

Date.	Locality.	Weight of Leaves.	%age Yield of Oil.	$d\frac{15}{15}$	α^{20}_{D}	n^{20}_{D}	Solubility in 8% Alcohol (by weight)	Ester No. 1½ hrs. hot.	Ester No. after Acetylation.
20/11/1923	Bundanoon, N. S. Wales	18 lbs.	0.82%	0.8917	+10.55°	1.4752	5.0	21.2	—
23/4/1924	Monga, N. S. Wales	122 lbs.	0.5%	0.9022	+6.85°	1.4790	4.6	9.9	44.7
17/6/1924	Wentworth Falls, N. S. Wales (Valley of the Waters).	39 lbs.	0.7%	0.9035	+7.25°	1.4791	5.0	8.3	60.9

For the purpose of this investigation the crude oils from all three consignments were mixed together, shaken with 8% sodium hydroxide solution, and finally saponified with alcoholic potassium hydroxide solution at room temperature.

The phenol and ester free oil was then subjected to fractional distillation with the following result:—

No.	B.pt.	Volume.	$d\frac{15}{15}$	α^{20}_D	n^{20}_D	Cineol
1	60–70 (20 mm)	130 c.c.	0.8814	+10.6°	1.4696	25%
2	70–75 (20 mm)	80 c.c.	0.8867	+ 5.35°	1.4711	31%
3	75–90 (20 mm)	16 c.c.	0.8898	+ 3.9°	1.4720	40%
4	90 (20)–105 (10 mm)	11 c.c.	0.9096	+ 6.3°	1.4790	——
5	105–125 (10 mm)	20 c.c.	0.9277	+ 7.8°	1.4920	——
6	125–150 (10 mm)	36 c.c.	0.9525	+ 9.5°	1.5036	——

Residue—

Determination of α and β Pinene.

50 c.c. of *Fraction* 60–70 (20 mm) were taken and the cineol removed by means of 50% resorcin solution. The volume of terpene now measuring 32 c.c. was fractionally distilled over metallic sodium at 767 mm. The first drops passed over at 160° C.

B.pt.	Volume.	$d\frac{15}{15}$	α^{20}_D	n^{20}_D
161–165°	17 c.c.	0.8614	+18.3°	1.4719
165–168°	10 c.c.	0.8617	+13°	1.4755

The fraction distilling below 165° on treatment with amyl nitrite in hydrochloric-acetic acid solution in the usual way yielded a nitrosochloride which, on purification, melted with decomposition at 115°.

Both fractions on oxidation with potassium permanganate in the presence of sodium hydroxide gave a good yield of sodium nopinate. The nopinic acid on liberation by means of dilute sulphuric acid and recrystallisation from benzene melted at 127°. Limonene, dipentene and phel-

landrene were not detected, but a small quantity of cymene not attacked by cold dilute potassium permanganate solution was observed.

The second fraction, measuring 80 c.c., was similarly treated with 50% resorcin solution for the removal of cineol. The resultant terpene measuring only 40 c.c. was fractionally distilled over metallic sodium at 762 mm. The first drops passed over at 164°.

B.pt.	Volume.	$d\frac{15}{15}$	a^{20}_D	n^{20}_D
Below 170°	16 c.c.	0.8626	+11.3°	1.4758
„ 175°	20 c.c.	0.8624	+ 5.95°	1.4800

The first fraction was found to contain much β pinene. The principal terpenes have been definitely identified as α and β pinene.

Determination of Cymene.

The fraction boiling below 175° referred to above was treated with 0.5% potassium permanganate solution at room temperature. The whole of the terpene was not removed in this way although the unattacked oil, measuring 14 c.c. had B. pt. 171–174° (uncorr.) $d\frac{15}{15}$, 0.8628 and n^{20}_D, 1.4818, the optical rotation was only reduced to +4.7°. However, it was oxidised by the method of Wallach (Liebigs Annalen, 1891, 264, 10) when an excellent yield of p-hydroxyisopropylbenzoic acid resulted. On recrystallisation from ethyl alcohol the crystals melted at 156–157°. The presence of cymene in quantity was thus confirmed.

The third fraction B. pt. 75–90° (20 m.m.) was found to consist of β pinene, cymene and cineol.

Determination of Cineol.—This constituent was regenerated from various resorcin washings and after distillation over metallic sodium at 770 mm., possessed the following characters:—

B.pt. 173-176° (uncorr.) $d\frac{15}{15}$, 0.9287-0.930; a^{20}_{D}, +1°; n^{20}_{D}, 1.4590; Congealing point −3° to −5°.

It reacted with phosphoric acid and formed the Iodol derivative melting at 112°.

Unidentified alcohol.—A small quantity of alcohol which appeared to be present both free and combined with isobutyric acid was detected with fraction distilling at 90-105° separated on redistillation of fraction No. 5.
It had $d\frac{15}{15}$, 0.915; a^{20}_{D}, +7.3; n^{20}_{D}, 1.4806.

It yielded on treatment with naphthylisocyanate very small amounts of a naphthylurethane melting at 120°. It appeared to be identical with the unidentified alcohol detected in the essential oil of *Baeckea Gunniana*, var. *latifolia*. (See this Journal, Vol. LVIX. (1925), page 355.) It did not react with phthalic anhydride either at or below 140°, nor could a crystalline nitrosochloride be prepared.

Determination of Sesquiterpene and Sesquiterpene Alcohol.

The 6th fraction containing both sesquiterpene and alcohol was repeatedly redistilled over metallic sodium at 10 mm. when the following fractions were obtained:—

B.pt.	Volume	$d\frac{15}{15}$	a^{20}_{D}	n^{20}_{D}
130–140 (10mm.)	9 c.c.	0.9416	+8.65°	1.5012
140–150 (10mm.)	16 c.c.	0.9555	+9.75°	1.5050

Both fractions gave the usual colour reactions typical of sesquiterpenes, but failed to yield any crystalline derivatives.

Determination of Phenolic Constituents.

The sodium hydroxide solution used in washing the crude oil, was treated with dilute sulphuric acid and the liberated phenols taken up in ether. After removal of this solvent 4.7 grams of yellow viscous highly refractive oil remained. The oil distilled at 140°–150° at 5 mm. and had refractive index of 1.4978. It did not combine

with concentrated ammonia solution but gave a vivid dark red colouration with ferric chloride in ethyl alcohol solution. It represents a mixture of phenols belonging to the Tasmanol group.

Determination of acids present as Esters.

The alkaline liquor from the saponification of esters was treated with sulphuric acid solution and the liberated volatile acids brought over in a current of steam. The greater portion was soluble in water, but a small quantity of oily acid floated on the surface. This latter was separated and examined apart from the former.

The silver salts were prepared in the usual way after neutralisation with ammonia solution. They gave the following results on ignition:—

Aqueous acid.

0.5522 gram silver salt gave 0.3020 gram silver=54.79% Ag.

Oily acid.

0.0760 gram silver salt gave 0.0388 gram silver=51.05% Ag.

The silver salt of isobutyric acid requires 55.4% Ag.

The silver salt of isovaleric acid requires 51.68% Ag.

The acid consists therefore of isobutyric and isovaleric acid. This conclusion was supported by qualitative reactions, which also showed the former to preponderate.

In conclusion, my thanks are again due to Mr. F. R. Morrison, A.A.C.I., F.C.S., Assistant Economic Chemist for valuable assistance in the investigation of Australian Essential Oils.

THE MOISTURE CONTENT OF SOME EUCALYPTUS WOODS.

By M. B. WELCH, B.Sc., A.I.C.,
Economic Botanist, Technological Museum.

(Read before the Royal Society of New South Wales, Nov. 2, 1927.)

A very widespread idea exists among those engaged practically in the timber trade and others, that there is a definite seasonal variation of the moisture content in trees, the sap being supposed to rise in the spring and to fall in the winter. The inference is that the moisture content of the wood of the tree, and therefore the freshly-felled log is greater in the spring and early summer and is less in the late autumn and winter. This explanation is frequently put forward to explain why a tree for milling purposes is preferably felled in the winter, since less drying or seasoning is required, and further that timber cut during that period "behaves" better. Undoubtedly, winter felling has a number of advantages, but the supposed reduction of the moisture content during the winter season is not one of them.

Although in text-books published about the end of last century, the theory of the rise and fall of sap was still seriously advanced; during more recent years investigation in Europe and America has proved the fallacy of the idea, e.g., Record* points out that "so far as the sap is concerned, there is fully as much, if not more during the winter than the summer. Winter-cut wood is not drier, to begin with, than summer felled—in fact, it is likely to be wetter."

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* Record, S. J. The Mechanical Properties of Wood, 1914.

Little appears to have been published with regard to the moisture contents of the Eucalypts. Patton, evidently referring to the wood of *E. regnans*, the Giant Gum of Victoria, gives the following figures as the moisture of one tree:—Central portion 150%, Outer Heartwood 77%, Sapwood 110%. Three papers have been published by Craib, in which the results of a careful examination made on the moisture distribution of several species of trees are recorded. There is a marked variation shown in the moisture content at different places in the wood, but with one exception there is, in general, an increase towards or near the central region.

Immink*, in an examination of one log of Teak, *Tectona grandis*, has found that the outer portion of the wood contained most moisture, whilst in two others, felled at the same time, the outer part was the driest.

The following results are based on an examination of four species of *Eucalyptus* growing in the vicinity of Sydney on the Hawkesbury sandstone formation, namely, *E. eugenioides* Sieber, White Stringybark; E. *piperita* Smith, Sydney Peppermint; *E. haemastoma* var. *micrantha* Bentham, White or Scribbly Gum (E. micrantha DC.), and *E. Sieberiana* F. v. Mueller, Coast, Black, or Mountain Ash. Growing on poor siliceous soil, the trees showed extremely slow growth. The wood was dense and heavy, and the sapwood and heartwood were well defined. Trees

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Patton, R. T. On the Drying of Timber, Proc. Roy. Soc. Victoria, 35, p. 64, 1922.

Craib, W. G. Regional spread of moisture in the Wood of Trees, Notes from the Royal Botanic Gardens, Edinburgh, I. vol. XI., No. li, 1918, II. vol. XII., No. lix, 1920, III. vol. XIV., No. lxvi., 1923.

* Immink, D. H. Distribution of moisure in a green log. Forest Research Institute, Buitenzorg.

about six inches in diameter inside the bark were selected, and after felling, a section, about eighteen inches long, was cut off and brought to the Museum, the bark being intact. A transverse section ⅜in. in thickness was cut through the centre of the billet, where possible on the same day as the tree was felled, and the moisture sections immediately weighed. Where this was not practicable the billet was wrapped in oiled paper as soon as possible after felling, to reduce the possibility of end moisture losses, and the moisture sections cut early on the following day.

In the later tests the heartwood was divided into two portions by separating the inner and outer parts, the diameter of the inner circle being half that of the total heartwood, though of course the area was only a quarter.

All moisture percentages are calculated on the dry weight of the wood.

Eucalyptus eugenioides, Sieber—

		Locality,	Moisture Content.
1.	Date, 26/6/'22	Middle Harbour.	
	Sapwood	.. .. ..	93.6%
	Heartwood	.. .. ..	95.8%
2.	Date, 11/10/'22	Middle Harbour.	
	Sapwood	.. .. ..	79.1%
	Heartwood	.. .. ..	88.5%
3.	Date, 12/2/'23	Middle Harbour.	
	Sapwood	.. .. ..	76.5%
	Heartwood	.. .. ..	78.4%
4.	Date, 18/7/'23	Middle Harbour.	
	Sapwood	.. .. ..	104.4%
	Heartwood	.. .. ..	111.1%
5.	Date, 3/10/'24	Hazelbrook.	
	Sapwood	.. .. ..	73.5%
	Outer Heartwood	.. ..	77.2%
	Inner Heartwood	.. ..	70.8%

	Locality,	Moisture Content.
6. Date, 12/1/'25	Faulconbridge.	
Sapwood		66.6%
Outer Heartwood		63.6%
Inner Heartwood		60.4%
7. Date, 30/3/'25	Faulconbridge.	
Sapwood		72.1%
Outer Heartwood		69.8%
Inner Heartwood		77.6%

Eucalyptus piperita, Smith—

1. Date, 26/6/'22	Middle Harbour.	
Sapwood		107.0%
Heartwood		104.7%
2. Date, 11/10/'22	Middle Harbour.	
Sapwood		129.7%
Heartwood		122.9%
3. Date, 12/2/'23	Middle Harbour.	
Sapwood		110.0%
Heartwood		131.2%
4. Date, 18/7/'23	Middle Harbour.	
Sapwood		111.5%
Heartwood		63.0%
5. Date, 3/10/'24	Hazelbrook.	
Sapwood		122.8%
Outer Heartwood		139.0%
Inner Heartwood		139.7%
6. Date, 12/1/'25	Faulconbridge.	
Sapwood		78.8%
Outer Heartwood		77.7%
Inner Heartwood		89.3%
7. Date, 30/3/'25	Faulconbridge.	
Sapwood		103.4%
Heartwood		117.0%

Eucalyptus haemastoma var. micrantha, Bentham—

		Locality.	Moisture Content.
1.	Date, 14/7/'22	Middle Harbour.	
	Sapwood	.. .. ..	91.7%
	Heartwood	.. .. ..	90.1%
2.	Date, 11/10/'22	Middle Harbour.	
	Sapwood	.. .. ..	100.4%
	Heartwood	.. .. ..	98.1%
3.	Date, 12/2/'23	Middle Harbour.	
	Sapwood	.. .. ..	76.5%
	Heartwood	.. .. ..	78.4%
4.	Date, 21/7/'23	Middle Harbour.	
	Sapwood	.. .. ..	93.1%
	Heartwood	.. .. ..	92.1%
5.	Date, 29/9/'24	Hazelbrook.	
	Sapwood	.. .. ..	100.5%
	Outer Heartwood	.. ..	96.0%
	Inner Heartwood	.. ..	92.2%
6.	Date, 13/1/'25	Hazelbrook.	
	Sapwood	.. .. ..	116.4%
	Outer Heartwood	.. ..	109.8%
	Inner Heartwood	.. ..	119.4%
7.	Date, 30/3/'25	Hazelbrook.	
	Sapwood	.. .. ..	88.5%
	Outer Heartwood	.. ..	87.6%
	Inner Heartwood	.. ..	95.6%

Eucalyptus Sieberiana, F. v. Mueller—

1.	Date, 14/7/'22	Middle Harbour.	
	Sapwood	.. .. ..	68.9%
	Heartwood	.. .. ..	79.3%
2.	Date, 11/10/'22	Middle Harbour.	
	Sapwood	.. .. ..	84.2%
	Heartwood	.. .. ..	129.6%

		Locality,	Moisture Content.
3.	Date, 12/2/'23	Middle Harbour.	
	Sapwood	.. .. ..	78.0%
	Heartwood	.. .. ..	102.5%
4.	Date, 21/7/'23	Middle Harbour.	
	Sapwood	.. .. ..	72.1%
	Heartwood	.. . ..	44.7%
5.	Date, 29/9/'24	Hazelbrook.	
	Sapwood	.. .. ..	88.2%
	Heartwood	.. .. ..	97.2%
6.	Date, 13/1/'25	Hazelbrook.	
	Sapwood	.. .. ..	94.3%
	Outer Heartwood	.. ..	104.2%
	Inner Heartwood	.. ..	118.9%
7.	Date, 30/3/'25	Hazelbrook.	
	Sapwood	.. .. ..	90.5%
	Outer Heartwood	.. ..	93.6%
	Inner Heartwood	.. ..	91.4%

In *E. eugenioides*, it appears that there is a fairly even moisture distribution as far as the two or three regions into which the transverse log sections were divided, the maximum variation being 9.4% between the sapwood and heartwood, the latter being the greater, in a log obtained from Middle Harbour on 11/10/'22. The maximum moisture content in both sapwood and heartwood, 104.4% and 111.1%, was found in a log from Middle Harbour, 18/7/'23. In one log (Faulconbridge, 12/1/'25), the moisture content was greatest in the sapwood; in one case it exceeded that in the inner heart (Hazelbrook, 3/10/'24), and in one case exceeded that in the outer heart (Faulconbridge, 30/3/'25). In the remaining four specimens, the heartwood content was greater. The sapwood moisture varied from 66.6% (Faulconbridge, 12/1/'25) to 104.4% (Middle Harbour, 18/7/'27), whilst the heartwood varied

from 60.4% (Faulconbridge, 12/1/'25, inner heart) to 111.1% (Middle Harbour, 18/7/'23).

E. piperita, with the marked exception of the specimen obtained from Faulconbridge, 12/1/'25, showed a sapwood moisture content of over 100%. Considerable variation in the sapwood and heartwood moistures was found in Middle Harbour 12/2/'23 and 18/7/'23, the figures being 110%, 131.2%, 111.5%, and 63.0% respectively. In three specimens, the moisture was greater in the sapwood, and in one it exceeded that in the outer heart (Faulconbridge, 12/1/'25). The sapwood varied from 78.8% (Faulconbridge, 12/1'25) to 129.7% (Middle Harbour, 11/10/'22), whilst the heartwood gave from 63.0% (Middle Harbour, 18/7/'23) to 131.2% (Middle Harbour, 12/2/'23).

E. haemastoma var. *micrantha* gave four specimens with the maximum moisture content in the sapwood, whilst in two of the remainder it was greater than in the outer heartwood. A variation occurs in the sapwood of from 76.5% (Middle Harbour, 12/2/'23) to 116.4% (Hazelbrook, 13/1/'25), and in the heartwood, from 78.4% (Middle Harbour, 12/2/'23) to 119.4% (Hazelbrook, 13/1/'25; inner heart).

E. Sieberiana, with one exception (Middle Harbour, 21/7/'23) showed a minimum moisture content in the sapwood. The sapwood moisture content varied from 68.9% (Middle Harbour, 14/7/'23) to 94.3% (Hazelbrook, 13/1/'25), whilst the heartwood varied from 44.7% (Middle Harbour, 21/7/'23) to 129.6 (Middle Harbour, 11/10/'22).

Dealing now with the seasonal moisture contents, *E. eugenioides* showed the highest figures in the two samples (1) and (3) obtained in winter, and a minimum in No. 6, felled in midsummer. *E. piperita* gave a maximum in

the heartwood of No. 5, obtained in spring, and also high results in No. 2, examined in the spring. Apart from the low heartwood figure in No. 4 (winter), the minimum average moisture was found in No. 6 (midsummer). *E. haemastoma* var. *micrantha,* showed the reverse of the preceding species, the maximum figures being obtained in No. 6 (midsummer), and the minimum in No. 3 (late summer). *E. Sieberiana* gave the maximum average figures in No. 6 (midsummer), and the minimum in No. 4 (winter), whilst No. 1 (winter) figures were also lower than the others.

Thus in two species a maximum was found to occur in midsummer, and in one species in winter and in spring. A minimum was found in two species in midsummer; in one species in late summer, and in one species in winter.

The density of the wood naturally has an effect on the total amount of free water which the cells are able to hold, since obviously a wood with a low density, and hence a small amount of cell substance can contain more water than one in which the wood is dense, with a corresponding reduction in cell cavity volume. Whilst the actual billets from which these moisture figures were obtained were not kept, the woods were all of approximately even density, being grown under similar conditions, and the variation in this factor could not appreciably affect the result. Koehler*, after Tiemann, shows a graph in which the maximum moisture content possible with various densities is indicated.

A number of tests has shown the following densities in lbs. per cubic foot, for the various woods under discussion. *E. eugenioides*: 53.7—57.1; *E. piperita*: 49.3—56.0; *E. haemastoma* var. *micrantha*: 51.2—56.5; *E. Sieberiana*: 51—57.3.

* Koehler, A. The Properties and uses of Wood, 1924.

The figures are based on air-dry volume and weight, i.e., approximately 12% moisture.

In order to see whether any connection could be traced between the rainfall for a period prior to the time of felling and the moisture content of the wood, the following table* is given. The nearest locality to Faulconbridge for which figures were available was Springwood, a few miles distant:—

AT SYDNEY.

Rainfall prior to—	Period.		Period.	
26/6/'22	1 month,	2.21 inches.	1 week,	0.45 inches
14/7/'22	1 „	4.03 „	1 „	0.56 „
11/10/'22	1 „	3.85 „	1 „	0.00 „
18/7/'23	1 „	8.34 „	1 „	0.23 „
21/7/'23	1 „	8.34 „	1 „	0.07 „

AT SPRINGWOOD.

Rainfall prior to—	Period.		Period.	
29/9/'24	1 month,	0.94 inches.	1 week,	0.66 inches
3/10/'24	1 „	2.38 „	1 „	1.52 „
12/1/'25	1 „	1.79 „	1 „	0.79 „
13/1/'25	1 „	1.79 „	1 „	0.00 „
30/3/'25	1 „	3.32 „	1 „	0.50 „

Combining the four species, the average moisture contents are as follows:—

	Moisture. Sapwood.	Moisture. Heartwood.
June-July, 1922	90.3%	92.5%
October, 1922	98.4%	109.8%
February, 1923	85.3%	97.6%
July, 1923	99.3%	77.7%

* The figures on which this table is based were obtained by the courtesy of the Commonwealth Meteorologist, Mr. H. A. Hunt.

	Sapwood	Outer Heartwood	Inner Heartwood
September-Oct., 1924	96.3%	102.4%	100.0%
January, 1925	89.0%	88.8%	97.0%
March, 1925	88.6%	92.0%	95.4%

On the whole, there is a greater moisture content shown in the heartwood, with the exception of the very pronounced diminution observed in July, 1923. The month prior to the felling was a particularly wet one, over eight inches of rain being recorded. An examination of the individual species shows that in *E. piperita* and *E. Sieberiana* there was a considerable increase in sapwood moisture at that time, whereas *E. eugenioides* and *E. haemastoma* var. *micrantha* show only a slight increase. There is not a great variation between the inner and outer heart, although the former, at two out of three periods, shows a greater moisture content.

The month prior to the end of September, 1924 was comparatively dry, but the moisture contents are higher than those obtained for trees felled at the end of March of the same year in the same locality, after a period of heavier rainfall, and, further, are much higher (with the exception of the sapwood) than the figures obtained for July, 1923. It does not appear that there is any very noticeable relationship, as far as the figures given are concerned, between rainfall and moisture content, especially where individual trees are considered. Thus one species may show a considerable increase in moisture content and another a reduction, although both are felled at the same time, in the same locality, and have been subject to the same conditions.

Further, combining the figures for approximately the same periods, and also combining the outer and inner heart moistures, the following results are obtained:—

	Sapwood. Moisture Content.	Heartwood. Moisture Content.
January-February	87.2%	95.3%
March	88.6%	93.7%
June-July	94.8%	85.1%
September-October	92.4%	105.5%

Although the maximum moisture content is shown in the winter felled sapwood and the minimum occurs in the winter felled heartwood, the variations are not great, and with a larger number of tests the figures for the different periods would, in all probability, show greater constancy.

Undoubtedly there is possible a considerable variation in moisture content between the heartwood and sapwood, or in different parts of the heartwood, but there is nothing to indicate that this variation is or is not more or less constant during different periods of the year, in any particular tree. The variations are too great to be accounted for by any change in density of the wood.

The variation in moisture content which occurs in individual trees between the heartwood and sapwood, and in the same species, at different periods, is such that it appears only possible to regard it as being due to physiological or ecological factors affecting the particular tree.

THE CAUSE OF BLUEING IN RED ROSES.

By Geoffrey S. Currey, F.C.S.

(Read before the Royal Society of New South Wales, Nov. 2, 1927.)

It has long been known among rose growers, in all parts of the world, that the petals of red roses often lose their true red colour and assume a more or less slaty-blue hue (commonly known as "blueing"); this defect is much more noticeable in some varieties than in others. The object of the following investigation was to try to discover the reason for this blueing, since, as far as the author is aware, no explanation has ever been published as to its cause.

From a knowledge of the chemical properties of the pure colouring matters isolated from various flowers by the author*†‡, it appeared probable that blueing was due to lack of acidity in the cell sap in which the colouring matter is dissolved. The results obtained have shown that this explanation, viz.: lack of acidity in the sap, is correct.

As mentioned above, blueing is much more noticeable in some varieties than in others, therefore it was decided to examine a kind which has a tendency to blue badly, and also one which seldom shows this defect, in order to see if the constituents of the petals were the same in both cases. As representing the blueing type, "Hadley" was chosen, while "Lady Maureen Stewart" was selected as the type which very seldom blues. The plants from which the flowers were gathered were grown at the nursery of Messrs. Hazlewood Bros. Ltd., Epping, N.S.W.

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* Roy. Soc. Proc., B., vol. 93, (1922).
† Chem. Soc. Trans., vol. 121, (1922).
‡ Roy. Soc. Proc., B., vol. 96, (1924).

The water content of the fresh petals amounted to 85.1% in "Hadley" and 86.4% in "Lady Maureen Stewart," and the mineral matter amounted to 3.09% in "Hadley" and 2.35% in "Lady Maureen Stewart" (calculated on the dried petals). The quantities of the individual constituents of the ash were practically the same in both varieties of rose, hence they apparently play no part in causing "Hadley" to blue.

The anthocyanin pigments were found to be identical in both varieties, hence the tendency of "Hadley" to blue cannot be explained on the grounds that it contains a different pigment from that contained in "Lady Maureen Stewart."

"Hadley" was found to contain much less tannin than "Lady Maureen Stewart," and the tendency of the former to blue was found to be due to this cause.

Experimental Part.

Analysis of the Ash.

	"Hadley"	"Lady Maureen Stewart"
Silica	6.25%	4.47%
Iron and Alumina	1.35 „	1.48 „
Lime	4.50 „	4.65 „
Magnesia	9.19 „	8.12 „
Sulphur	2.27 „	1.51 „
Phosphorus	5.81 „	5.56 „
Soda	0.86 „	1.58 „
Manganese	Trace	Trace
Carbonates and Chlorides	Trace	Trace
Potash	48.87%	47.94%
Solubility of ash water	74.00 „	73.50 „
Alkalinity of aqueous extract of ash expressed at K_2O	34.26 „	35.50 „

The anthocyanin pigments.

In order to determine approximately the amount of anthocyanin pigment present in the petals of both "Hadley" and "Lady Maureen Stewart," fresh petals

were used, since it was found that some loss of pigment occurred, in both varieties, on air drying. Sixty grams of freshly gathered petals of "Hadley" and "Lady Maureen Stewart" were separately extracted with glacial acetic acid, by allowing them to stand for several days in closed vessels, in contact with this solvent. The extracts were then filtered, and the residues washed with acetic acid; to the combined filtrates and washings there were added small quantities of methyl alcohol (containing about 10% hydrochloric acid), and then 2½ times their volumes of ether; the mixtures were well agitated and allowed to stand several hours, when the pigments were precipitated as gummy masses; these were dissolved in boiling water, filtered from insoluble matter, and equal volumes of ethyl alcohol (containing 3% hydrochloric acid) added to the filtrates; on cooling, the pigments were obtained in crystalline form, as chlorides.

Quantities of crystalline pigments obtained:—

"Hadley"	"Lady Maureen Stewart"
60 grams fresh petals yielded .113 gram.	60 grams fresh petals yielded .194 gram.
Equivalent to 1.26% (calculated on dried petals).	Equivalent to 2.39% (calculated on dried petals).

To examine the chemical properties of these pigments, it was necessary to obtain larger quantities of them; for this purpose air dried petals were used and the extractions were made by the method used by Willstätter and Nolan, in their examination of the pigment of *Rosa gallica*.* One hundred grams of the air dried petals of "Hadley" and 100 grams of those of "Lady Maureen Stewart" were separately extracted with methyl alcohol (containing 2% hydrochloric acid, to prevent pseudo-base formation); after filtration the residues were washed with methyl-alcohol (containing 1% hydrochloric acid). The filtrates and washings were

* Annalen, 1915. Vol. 408, pp. 1-14.

united, and mixed with 2½ times their volumes of ether, which caused the precipitation of the pigments in the form of dark brown sticky masses, from which the ether-alcoholic liquors were readily decanted. It was noticed that the filtrate obtained from the petals of "Lady Maureen Stewart" possessed a more intense red colour than that obtained from the petals of "Hadley," indicating a larger quantity of pigment in the former. The crude pigments thus obtained were allowed to stand in contact with small quantities of a mixture of methyl-alcohol and glacial acetic acid for about 24 hours; by this treatment the pigments were obtained in the form of dark brown powders which were collected, washed with small quantities of methyl-alcohol, and finally converted into crystalline form by solution in boiling water, filtering, and adding to the hot filtrates equal volumes of ethyl alcohol (containing 3% hydrochloric acid). On cooling, the pigments separated out in the form of red-brown leaflets, possessing a fine golden lustre.

For identification purposes, the crystalline pigments were tested in respect of the following characteristics, viz.: crystalline form, colour, and reflex of the crystalline chloride; solubility in water, alcohol, acetone, and dilute hydrochloric acid (1% and 1½%); reaction with lead acetate, ferrichloride (in aqueous and alcoholic solutions), sodium carbonate, sodium hydroxide, calcium carbonate and sodium bisulphite; the effect of allowing dilute aqueous solutions to stand; and finally, the distribution of pigment between amyl alcohol and dilute aqueous acid.

The Tannin.

About 400 grams of the air dried petals of "Hadley" and about 170 grams of petals of "Lady Maureen Stewart" were separately extracted with boiling water, the extracts strained through calico and concentrated to about one half

their bulks; the concentrated extracts were deep red in colour, turbid, and possessed a bitter and astringent taste, and reacted acid to litmus. After allowing to cool, both extracts were repeatedly agitated with ethyl acetate, and the yellow extracts thus obtained after agitation with sodium chloride, and filtration, were evaporated to dryness under reduced pressure. The residues consisted of puffed up masses of glistening scales, which, when powdered, possessed a yellow colour. The residue from "Hadley" appeared to be identical with that obtained from "Lady Maureen Stewart."

A comparison of the properties of the tannin isolated from both varieties of Rose showed that they undoubtedly consisted of the same substance, and it has already been shown that the anthocyanin pigment is the same in both varieties. The next step in the work was to show that the tannin was capable of forming an oxonium salt with the anthocyanin pigment; this was accomplished by dissolving pure cyanin chloride in water and allowing the solution to stand until decolourised; on adding some of the tannin, the red colour of the solution was restored.

Having shown that the tannin was capable of forming an oxonium salt with the cyanin, the next question which presented itself was:—Do the petals contain any other acids capable of stabilising the red colour, or is tannin the only acid present? This point was elucidated by means of the following experiments:—Aqueous extracts were separately made from fresh petals of "Hadley" and "Lady Maureen Stewart," and each extract was divided into several portions; one portion of the extract from "Hadley" and one from "Lady Maureen Stewart" were each left as extracted, while to the others, various organic acids were added (citric, malic, tartaric, etc.), in small quantities. To each

extract, well washed hide powder was added and well stirred. It was observed that the extracts to which nothing had been added soon lost their fine red colours, changing to a dirty bluish pink and finally, becoming practically colourless, while the extracts to which the organic acids had been added retained their red colours. Both the extract from "Hadley" and that from "Lady Maureen Stewart" behaved in exactly the same manner. The reason why those extracts, to which no organic acids had been added, lost their red colours, is due to the fact that the tannin contained in them was absorbed by the hide powder, while in those to which the organic acids had been added, although the hide powder removed the tannin, the presence of the other acids prevented decolourisation (since tannin is the only acid removed by hide powder).

As an additional proof that tannin is the only acid present, the decolourised extracts were filtered off from the hide powder and tested with litmus and by taste.

It was found that all acidity had disappeared, and also all astringency and bitterness; on adding tannin to these solutions, the red colours were restored.

The reason why the colours of these extracts disappeared on the treatment with hide powder is due to the fact that, on removal of the tannin, the red oxonium compound of cyanin and tannin is broken up and the cyanin is present as the violet colour base and this, being unstable, soon passes to the colourless pseudo-base.

Since the tannin is only a weak acid, fairly large quantities are necessary to restore the red colour to a decolourised solution of cyanin. It would appear that "Lady Maureen Stewart," under normal conditions of growth, is capable of producing sufficient tannin to stabilise the red colour of the petals (it has been observed to blue in isolated cases), while

in "Hadley" the production of tannin varies; occasionally a bloom is met with which is quite indistinguishable in colour from "Lady Maureen Stewart."

The petals of "Hadley," from which the tannin was obtained in this work, were a very poor colour, and the small yield of tannin (7 grams from 400 grams petals), as compared with that obtained from "Lady Maureen Stewart" (6 grams from 170 grams petals), is quite in harmony with the above statements.

To confirm this opinion that blueing is due to lack of tannin, it was necessary to determine quantitatively the total tannin content in both varieties, in the case of "Hadley" in petals which showed signs of blueing, and also, in petals possessing a true red colour, and since there appears to be a direct relationship between the quantity of anthocyanin pigment and tannin (i.e., more pigment requires more tannin), the quantity of tannin in a rose devoid of anthocyanin, viz.: "Frau Karl Druschki," was determined at the same time. It was expected that (a) "Frau Karl Druschki" would contain the least amount of tannin, (b) the sample of "Hadley" showing signs of blueing would come next, (c) the sample of "Hadley" possessing a true red colour would contain somewhat more than (b), and finally, "Lady Maureen Stewart" would contain more tannin than any of the others, since it contains considerably more anthocyanin pigment.

The following figures show conclusively, that this is correct:—

Variety of Rose.	Tannin.	Soluble non-tannins.	Total soluble solids.
"Frau Karl Druschki"	3.42%	31.31%	34.73%
"Hadley" (showing signs of blueing)	6.33%	35.95%	42.28%
"Hadley" (true colour)	7.58%	34.00%	41.58%
"Lady Maureen Stewart"	11.62%	38.20%	49.82%

These determinations of tannin were made in the laboratory of the N.S.W. Dept. of Agriculture, through the courtesy of Mr. A. A. Ramsay, chief chemist, to whom the author desires to express his thanks. The British Official method, using chromed hide powder, was used.

Summary of Results.

1. The cause of blueing in red roses is due to insufficient tannin in the cell sap of the petals.

2. The anthocyanin pigment in "Hadley" is identical with that in "Lady Maureen Stewart," and consists of the di-glucoside Cyanin; the latter rose contains the larger quantity.

3. There appears to be a direct relationship between the quantity of anthocyanin pigment and tannin in red roses.

4. The tannin of "Hadley" is identical with the tannin of "Lady Maureen Stewart," but the latter contains a much larger quantity.

It is proposed to extend these investigations, to see if it is possible to increase the tannin content of "Hadley" and other roses susceptible to blueing, and thus remove this defect. In conclusion, the author desires to express his thanks to Mr. H. Hazlewood for supplying the roses necessary for this investigation, and for the interest and assistance given by him throughout the course of this work.

THE DETERMINATION OF MINUTE QUANTITIES OF METALS IN BIOLOGICAL MATERIAL.

PART 1.

THE DETERMINATION OF LEAD IN URINE.

By H. B. TAYLOR, M.C., D.Sc., F.A.C.I.

(Read before the Royal Society of New South Wales, Dec. 7, 1927.)

During the past three years, acting in collaboration with Dr. Charles Badham of the Division of Industrial Hygiene of New South Wales, an extended investigation has been made into the chemistry and pathology of lead poisoning. Portion of the results of this investigation has already been published.[10] The subject of this paper is a criticism of existing methods for the determination of lead in urine, with a detailed description of, and the results obtained with, a new method based on physico-chemical principles.

For many years the presence of lead in urine has received the attention of chemists in all parts of the world, and many methods, both chemical and electrolytic, have been devised for its determination. These methods in general have aimed at the destruction of the organic matter in the preliminary stages of the analysis, the separation of the lead from accompanying salts by either chemical or electrolytic means, and the final determination by some suitable chemical reaction.

Arsenic, copper, and zinc, have frequently been mentioned in the literature on the subject as being normally present in urine, but no reference has been made to a definite amount of lead. Since there is every reason to

believe that lead is also present, it would appear that methods such as are mentioned above are unable to determine it when present in amounts less than 0.05 mgm. per litre. It became necessary, therefore, to devise a method which would give the degree of accuracy required, and it was with this object that this investigation was undertaken.

In the determination of small quantities of lead of the order of 0.05 mgm. per litre of urine, any loss due to such a factor as solubility becomes of extreme importance, and even though this loss, by taking special precautions, may be greatly reduced, it cannot be eliminated, and must remain as a serious objection to any method which employs in any of its stages a separation of lead by means of the formation of a lead salt.

An example of a method which employs wholly chemical reactions is that of Avery.[1] A brief account of this method is as follows:—

> 1,000 c.c. of urine are evaporated to dryness in the presence of nitric acid and the residue heated in a muffle furnace until all the nitrates have been decomposed. The ash is then taken up in hydrochloric acid, neutralised, a definite quantity of hydrochloric acid added and the lead separated as the sulphide by means of sulphuretted hydrogen. The precipitate of sulphides is dissolved in nitric acid and the lead separated as the sulphate. The sulphate precipitate is then dissolved in ammonium acetate, and the lead finally determined colorimetrically by the addition of ammonium sulphide.

Although this method has considerable merit it cannot be considered as entirely satisfactory for the determination of very small quantities of lead, on account of the probable loss of lead during both the ignition and the separation as sulphide and sulphate. The solvent action of calcium chloride and hydrochloric acid on lead sulphide is well shown by Mertens[2] and Dede[3]. Since this salt is present in the ash from urine, it is highly probable that considerable loss takes place at this stage of the analysis.

The separation of lead from accompanying salts by electrolytic methods, although they overcome very largely the objections in regard to solubility, have not proved as efficient as might be expected. This is due mainly to a distribution of the lead between the anode and cathode when deposited electrolytically from a nitric acid solution, and also to the disturbing influence, on electrodeposition, of sodium and potassium chloride, which necessitates the continuance of the electrolysis until all the chlorine has been evolved. Attention has been drawn to these facts by Mellon[4], and by Schumn.[5] Minot[6] has also severely criticised an electrolytic method, with the result that this investigator has reverted to chemical means for lead determinations. From what has been said it is seen that there are serious objections to electrolytic methods, and it is doubtful whether such methods have any advantages over chemical ones.

It would appear that a method which combines the principles of electrolytic deposition and chemical reaction might prove successful in eliminating the objections which have been mentioned. Adsorption is a physical phenomenon, and has proved successful in removing small quantities of lead from solution. Fairhall[7] has shown that substances such as ignited bone and kelp charcoal, under suitable conditions, adsorb lead, and if it is possible to apply this principle of adsorption directly to urine, then a very great advance will have been made in lead determinations. Such a method, however, immediately raises the questions, how is the lead held in solution in the urine? Is it in organic combination, or as a salt, presumably a phosphate? It seems probable since the amount of organic matter in urine is so very much greater than the amount of lead, that if there were any tendency for the lead to enter into organic combination practically the whole of the lead would do so. If

lead so combined cannot be precipitated unless the organic matter is destroyed, then it would be expected that any method which is applied directly to the urine would fail to detect lead in amounts greater than perhaps a small fraction of what is actually present. Lead, however, can be precipitated by suitable methods which deal directly with the urine, and consequently it seems reasonable to conclude that whatever its form is, it behaves as an inorganic salt.

Fairhall[8] has devised a method which employs this principle of adsorption. This investigator considers that lead is present in blood and urine as a suspended or highly dispersed colloidal phosphate, and that on the addition of sufficient ammonium hydrate, the lead is carried down by entrainment with the precipitate of phosphates formed. There is no doubt that lead can be removed from urine by means of a phosphate precipitate, but it would appear that this removal is due to adsorption, and not to the suspended nature of the lead phosphate, as suggested. Lead phosphate in such a condition of suspension is somewhat difficult to conceive, particularly when it is considered that the amount of lead present is a great deal less than the solubility of lead phosphate in a solvent such as urine. It might be added that both zinc and copper are carried down together with lead by a phosphate precipitate, so that, if the theory of entrainment is to hold good, these metals also must be in a state of fine suspension, a condition which is highly improbable.

Fairhall's method is briefly as follows:—

Ammonium hydrate is added to a litre of urine until strongly ammoniacal. The precipitate of phosphates is allowed to settle, and the clear urine decanted. The precipitate is then freed from urine by filtration, ashed, taken up in hydrochloric acid, neutralised, and the lead precipitated as sulphide by sulphuretted hydrogen. The precipitate of sulphides is dissolved in nitric acid, boiled, neutralised, reacidified with acetic acid, and the lead precipitated as the

chromate. The precipitate of lead chromate is collected, washed, and dissolved in hydrochloric acid. Potassium iodide is then added and the iodine liberated titrated with 0.005 N. sodium-thio-sulphate (1 c.c. = 0.3451 mgm. lead).

This method, with the exception of the final determination, is a distinct advance on that of Avery, inasmuch as the probability of loss of lead through ignition is reduced, and the time required for an analysis very much decreased. The method is, however, unsatisfactory, on account of the probable loss of lead in the following stages:—

1. The precipitation of phosphates by the addition of an excess of ammonium hydrate.
2. The ignition of the phosphate precipitate.
3. The use of sulphuretted hydrogen for the precipitation of the lead.
4. The formation of lead chromate and the subsequent washing of the precipitate.
5. The employment of a titration method for the final determination, in which 0.10 c.c. of the sodium-thio-sulphate solution is equivalent to 0.03 mgm. lead.

To show that the amount of ammonium hydrate added to a urine in order to precipitate the earthy phosphates has an effect on the amount of lead precipitated, a series of determinations were made on a sample of urine to which different amounts of ammonium hydrate were added. The determinations were carried out as follows:—

To 1250 c.c. of urine a known amount of ammonium hydrate was added, and the precipitate formed allowed to settle. 1000 c.c. of the clear urine was then decanted, made neutral to methyl red with lead free hydrochloric acid, and its lead content determined by the adsorption method. This method is described later.

The results, which are given in Table 1, show quite clearly that the greater the amount of ammonium hydrate added, the greater is the amount of lead left in solution in the urine.

Table I.

Volume of Urine.	Ammonium hydrate added.	Lead left in solution per litre of decanted urine.
c.c.	grm.	mgm.
1250	0.75	0.02
1250	1.5	0.03
1250	2.5	0.03
1250	4.0	0.04

Similar results were obtained by the use of sodium in place of ammonium hydrate, and the following determinations were made on a sample of urine which contained 0.09 mgm. lead per litre. The lead content of this urine was determined by the adsorption method. The method employed to determine the amount of lead precipitated with the phosphates, was the same as that given by Fairhall, except that the sulphide precipitate was dissolved in nitric acid, boiled, neutralised, and the lead determined colorimetrically by the sodium-bi-sulphite reaction, described later. The figures given in the following table show that even with the addition of sodium hydrate, just sufficient to cause a precipitate of phosphates, there is a small loss of lead, and that this loss increases with an increase in the amount of sodium hydrate added. To confirm this loss the amount of lead was determined, by the adsorption method, in a litre made up of 500 c.c. of urine decanted from each of portions 2 and 3. The amount of lead found was 0.04 mgm., which is the mean of the losses from portions 2 and 3, as shown in the last column of Table II.

Table II.

	Volume of Urine.	Sodium Hydrate added.	Lead found per litre.	Lead lost per litre.
	c.c.	grm.	mgm.	mgm.
1	1000	1.0	0.08	0.01
2	1000	3.0	0.06	0.03
3	1000	7.5	0.04	0.05

From a consideration of results given in Tables I. and II., it is seen that a loss of 0.03 mgm. of lead per litre can very easily take place without a large excess of ammonium or sodium hydrate being added. Such an error in a determination on a sample of urine which does not contain more than 0.10 mgm. per litre, is obviously too large, and consequently a method which, in one stage of the analysis is liable to an error of this magnitude, must be considered unsatisfactory.

As pointed out by Mertens,[2] and other workers, complete precipitation of lead by sulphuretted hydrogen, does not take place from a solution which contains salts such as calcium chloride. Although other metals, such as copper and zinc, greatly aid the precipitation, it is very doubtful even when these metals, which also occur in urine, are present, whether the lead is completely precipitated.

The Determination of Lead.

The accuracy of any method for the determination of small quantities of lead, must necessarily depend on the amounts of lead lost and gained during the analysis. These amounts, although actually very small, are relatively large when the total amount of lead present in the material is taken into consideration. In dealing with these small quantities, it very often happens that an analysis is carried out without any apparent loss of lead, but this does not prove that no loss has taken place, rather does it go to show that the amounts of lead lost and gained during the analysis are approximately equal. It is, therefore, essential in devising a method that the quantities of lead to be determined,

the presence of lead in chemically pure reagents, and those factors on which accurate results depend, should be fully appreciated. From a consideration of what has previously been said, it would appear that, in order to get a method as free from objections as possible, the following principles should be taken into consideration.

1. The lead should be separated directly from the urine.
2. The number of stages in the analysis, and the quantities of reagents used, should be reduced to a minimum.
3. No means of lead separation should be employed which necessitates the formation of a lead salt.
4. The separation of lead from accompanying salts should be done by physico-chemical means—adsorption on suitable material.
5. The adsorbing material should be such that it can be easily eliminated.
6. Ignition, if unavoidable, should be carried out at a low temperature, in the presence of an alkaline salt.
7. The final determination should be preferably of a colorimetric nature.
8. The reagents used should be such that they can be obtained lead free by suitable means of purification.
9. The method should be capable of accurately determining lead in a urine which contains not more than 0.05 mgm. per litre.
10. The time required for an analysis should be short—not greater than 24 hours.

A method which for the most part fulfils the above conditions has been devised, and has given extremely satisfactory results. In it the lead is separated from the urine

by the use of calcium oxalate as the adsorbing material. This substance can be eliminated by first converting into the carbonate, at a temperature not sufficient to cause loss of lead through volatilisation, then into the chloride, and finally eliminated by making the solution slightly alkaline when the lead is precipitated together with a small amount of calcium phosphate. The final lead determination is then made by a reaction with sodium-bi-sulphite.

This reaction was investigated first by Ivanov[9], who found that when a solution of an acid sulphite is added to a solution of a lead salt, a white opalescence is produced which is proportional to the amount of lead present. This reaction, which is sensitive to one part of lead in two millions, has been subjected to further investigation, and has proved entirely satisfactory for the conditions under which it has been applied.

This method has been in use in the Department of Public Health, New South Wales, for the past 3 years, and during that time some 700 samples of urine have been examined for lead. These figures are given to show that this method has been thoroughly tested, and in the hands of a trained chemist, is capable of detecting as small an amount of lead as 0.005 mgm. per litre.

No method previously put forward can claim this degree of accuracy, and by its use the excretion of lead from persons not associated with lead in their daily work has been found to vary from 0.005 to 0.05 mgm. per litre.

Purification of Reagents.

The reagents used were:—

Hydrochloric acid.
Acetic acid.
Sodium hydrate (3.5% solution).
Ammonium oxalate (saturated solution).

Calcium chloride (10% solution).
Sodium-bi-sulphite (10% solution).
Chloroform.
Distilled water.

Of these the hydrochloric acid and sodium hydrate were found to be lead free in the quantities used, and required no purification. The remainder of the reagents all contained lead in sufficient quantities to render their use inadvisable without previous purification. The acetic acid and chloroform were obtained lead free by distillation. The solutions of ammonium oxalate and calcium chloride were made neutral to methyl red with hydrochloric acid boiled, and the lead completely removed by the addition of ignited animal charcoal, and subsequent filtration after standing from 2 to 3 hours with constant stirring. The solution of sodium-bi-sulphite was freed from lead by filtration until clear. The distilled water was obtained free from lead by distillation from lead free glass vessels. In addition to these reagents, all filter papers were found to contain small quantities of lead. The papers used were 7 and 9 cm. quantitative papers, and were freed from lead by washing each paper in the filter funnel with 1-3 hydrochloric acid, and then with lead free distilled water.

Since as small an amount of lead as 0.0025 mgm. in 5 c.c. of solution will give a definite reaction with sodium-bi-sulphite, it is essential to know that all reagents in the quantities used do not contain lead. To prove this, a litre of urine, which had been decanted from the calcium oxalate precipitate as detailed in the method of analysis was taken, the necessary reagents added, and the analysis for lead repeated. It was found that any lead present was derived from the reagents, and in this way an effective check was kept on their purification.

The specimens of urine were collected in glass bottles of 2-3 litre capacity, to which 10 c.c. of chloroform had been added. By this means the specimens were always in good condition when received at the laboratory, and could be kept for any desired period. Although the possibility of lead contamination from the reagents is eliminated by the methods of purification adopted, there still remained the possibility of lead being picked up from the containing bottles. To show that this did not take place, the lead content of a number of specimens of urine was determined before and after they had stood for a number of days. In no case was there an increase in the lead content of the urine.

Method of Analysis.

Since the underlying principle of this method is adsorption, it is necessary in the preliminary stage of the analysis to adjust the acidity of the urine to that at which optimum adsorption takes place. It has been found that lead in urine is completely adsorbed on calcium oxalate between the hydrogen ion concentrations of pH 4 and pH 5. These values correspond to a condition which is acid to methyl red, and alkaline to methyl orange, and is easily obtained by the addition, to the urine, of either acetic or hydrochloric acid.

The efficiency of this method depends very largely on the close attention paid to the details of the analysis, these, therefore, have been given very fully as follows:—

1. A litre of urine is taken and its acidity tested with methyl red paper; if alkaline, sufficient acetic or hydrochloric acid is added to make it neutral to methyl red; 2 c.c. 1: 1 acetic acid, 2 c.c. of 10% calcium chloride and 25 c.c. of a saturated solution of ammonium oxalate are then added, the contents of the beaker being well stirred after each addition.

2. After standing overnight the precipitate of calcium oxalate is separated from the greater portion of the urine by decantation.
3. The beaker containing the precipitate and about 25 c.c. of urine is heated on the water bath for about 5 minutes or until the precipitate becomes granular.
4. The precipitate is then separated from the liquid by passing through a 9 cm. filter and the contents of the filter washed once with distilled water.
5. The precipitate is then transferred to a small platinum dish by making a hole in the bottom of the filter and washing out with a jet of water. After the addition of 1 c.c. hydrochloric acid (conc.), the contents of the dish are evaporated to dryness on the water bath.
6. The dish is then heated over a small rose burner until the whole of the calcium oxalate is converted into carbonate. In this operation care must be taken that the temperature of the dish is raised sufficiently high to bring about the complete decomposition of the oxalate, and yet not high enough to cause loss of lead through volatization. In practice it is found that good results are obtained by placing a small piece of platinum foil over the dish, when complete conversion of oxalate takes place in about one hour, at a temperature below dull redness.
7. 2 c.c. of hydrochloric acid (conc.) are then added to the dish to convert the carbonate into chloride; the contents of the dish are evaporated on a water bath, and finally brought to dryness by heating over a small burner.
8. 10 c.c. of distilled water are then added to the dish, and 3-4 drops of approximately 1:10 hydrochloric acid, in order to dissolve any calcium oxide formed.

9. The solution, which should be quite clear, is then made just alkaline to methyl red with approximately 1:30 sodium hydrate, and filtered through a 7 cm. filter, the dish is washed out with the filtrate, and the contents of the filter washed once with distilled water. The lead at this stage is on the filter paper.

10. The filter paper is then treated in the filter funnel with 2 c.c. 1:10 hydrochloric acid, and the paper washed with small quantities of distilled water until the filtrate totals 7.5 c.c.

11. A solution of sodium hydrate approximately 1:30 is then added to the filtrate until it is faintly acid to methyl orange. The filtrate is then re-passed through the filter, made up to 10 c.c. by washing the filter paper with small quantities of water, and again adjusted so that it is faintly acid to methyl orange.

The amount of lead present is then determined by comparing the degree of opalescence produced on the addition of 1 c.c. of a freshly prepared 10 per cent. solution of sodium-bi-sulphite to 5 c.c. of the filtrate, with that of standards containing known amounts of lead. The standard solutions are made up so that they contain approximately the same amount of sodium chloride and phosphate as the filtrate to be tested. This is important, since the presence of a salt, such as sodium chloride, affects the physical character of the precipitate of lead sulphite, which is liable to cause an error in the determination. This standard salt solution contains approximately 12 grms. of sodium chloride and 0.35 grm. calcium phosphate to a litre, and is adjusted so that it is faintly acid to methyl orange.

The determination is carried out as follows:—

To six test tubes ½ in. x 5 in. are added amounts of lead from 0.005, 0.01 to 0.05 mgm., i.e., 0.05 to 0.50 c.c. of a solution of lead acetate (1 c.c. = 0.10 mgm. lead), and 5 c.c. of the standard salt solution. The contents of the tubes are mixed and to each is added 1 c.c. of the freshly prepared sodium-bi-sulphite solution. To 5 c.c. of the filtrate to be tested is added 1 c.c. of the sodium-bi-sulphite solution, and the degree of opalescence compared with those of the standard tubes.

In the above method, should any oxalate be not converted into carbonate (stage 6 of the analysis) it will be noticed that when the calcium chloride is taken up with water and a few drops of dilute acid added (stage 8) the solution will remain turbid. Should this take place, the contents of the dish must be evaporated to dryness, heated to convert the oxalate into carbonate, treated with a few drops of hydrochloric acid (concentrated), dried over a small flame, and again taken up with 10 c.c. of water, and a few drops of dilute hydrochloric acid.

If the analysis is continued when the solution at stage 8 is turbid, a precipitate of calcium oxalate will form on neutralisation with sodium hydrate (stage 11), which will completely remove the lead from solution.

The results of the analyses of a few samples of urine to which small amounts of lead have been added, are given in table 111.

Table III.

	Amt. lead added.	Amt. lead found.		Amt. lead added.	Amt. lead found.		Amt. lead added.	Amt. lead found.
	mgm.	mgm.		mgm.	mgm.		mgm.	mgm.
(1)	0.00	0.04	(2)	0.00	0.005	(3)	0.00	0.02
	0.01	0.05		0.02	0.02		0.05	0.07
	0.05	0.09		0.05	0.05		0.10	0.10
							0.20	0.20

The three samples of urine given above contained originally 0.04 mgm., 0.005 mgm., and 0.02 mgm. of lead per litre, and to these were added amounts of lead from 0.01 to 0.20 mgm. per litre. The results obtained, which are given in the above table, clearly indicate the degree of accuracy of which the method is capable. The loss of 0.02 mgm. of lead in the last analysis of sample No. 3 is due, not to incomplete precipitation of the lead, but to a small error in the determination, which is increased by the multiplication factor necessary when this quantity of lead is present.

The Effect of Tin, Barium, and Bismuth.

Of the metals other than lead which are likely to be present in a sample of urine, tin, barium, and bismuth, give re-actions with sodium-bi-sulphite somewhat similar to that of lead. Since their presence in the final solution (stage 11) interferes with the determination of the lead, it is essential to know if these metals are eliminated during the course of the analysis. To show that both tin and barium are eliminated during the analysis 1.0 mgm. of tin chloride was added to a litre of urine and 1.0 mgm of barium chloride added to another litre of the same sample, known to contain 0.02 mgm. of lead per litre. On analysis the amount of lead in each was found to be 0.02 mgm.; from this it is evident that the presence of tin and barium in the urine does not interfere with the lead determination. The same cannot be said of bismuth. This metal separates out as the oxychloride on the final neutralisation with soda (stage 11), and carries down with it practically the whole of the lead. It has been found, however, that if the solution is neutralised while hot the precipitate of bismuth-oxy-chloride separates out lead free

The Determination of Bismuth.

Should bismuth separate out in the final stage of the analysis for lead it can readily be determined as follows:—

The lead-free bismuth-oxy-chloride precipitate is dissolved on the filter paper with 5 c.c. of 1:10 hydrochloric acid. The filter is then well washed with distilled water, and the volume made up to 25 c.c. The amount of bismuth present is then determined in an aliquot portion by comparing the colour produced on the addition of one drop of a 10 per cent. solution of sodium sulphide with standards containing known amounts of bismuth. A precipitate of bismuth can readily be distinguished from calcium oxalate by testing the solution with potassium iodide paper. The presence of bismuth is indicated by a bright yellow colour.

The Lead Excretion of Workers in Various Industries.

The co-relation of lead excretion with clinical symptoms, and details of the work engaged in, of a large number of the cases examined, are contained in the Reports of the Director-General of Public Health, N.S.W., 1924-1925[10]. It is not intended to repeat the details of these examinations in this investigation, but it was thought that a summary of the amounts of lead excreted by persons in various industries might be of value. A table has accordingly been prepared, which gives the lead excreted in the urine of 330 cases which have been examined. In the following table the nature of the work, the total number of cases examined, and the number of cases which excreted lead within the limits mentioned, are given:—

It is seen that in general the amount of lead excreted in the cases examined was less in those trades in which the exposure to lead dust is not so evident. Of the 70 cases in group I., 47 excreted lead in quantities greater than 0.10 mgm. per litre, whereas of the 16 cases not ex-

Table IV.

Nature of Work.	Total No. Examined.	Excretion of lead mgm. per litre of urine. 0.00 to 0.05	0.06 to 0.10	0.11 to 0.15	0.16 to 0.20	0.21 to 0.25	0.26 to 0.50	0.51 to 1.00	1.01 to 1.50	Remarks
Manufacture of whitelead and lead accumulators.	70	13	10	12	3	13	12	6	1	
Painters	185	81	51	30	12	5	6	—	—	Lead Paint.
Plumbers	8	1	5	1	1	—	—	—	—	
Potters	27	12	9	3	1	—	2	—	—	
Metal Workers	15	7	5	1	1	—	1	—	—	Tinning etc.
Printers	15	9	4	1	—	—	1	—	—	
Miscellaneous	16	13	3	—	—	—	—	—	—	Not associated with lead.

posed to lead in their daily work, there were not any who excreted more than 0.10 mgm. The greatest quantity of lead excreted was by a lead-worker employed in the manufacture of lead accumulators, and amounted to 1.12 mgm. per litre.

Of those cases which excreted lead within the limits of 0.26 and 0.50 mgm. per litre, the two potters were employed as dippers using unfritted lead glaze, and gave figures of 0.32 and 0.30 mgm. per litre respectively. The metal-worker was employed tinning sheet-metal, and excreted 0.40 mgm. per litre. The printer was a compositor, and excreted 0.30 mgm. per litre.

Of the cases included in the above table, 68 were diagnosed by Dr. Charles Badham, Medical Officer in charge of the Division of Industrial Hygiene, N.S.W., as suffering from lead poisoning. The excretion of these cases is summarised in the following table:—

Table V.

Nature of Work.	Total No. of Cases.	Excretion of lead mgm. per litre urine. 0.00 to 0.05	0.06 to 0.10	0.11 to 0.15	0.16 to 0.20	0.21 to 0.25	0.26 to 0.50	0.51 to 1.00	1.01 to 1.50
Lead Workers	41	4	3	7	2	8	10	6	1
Painters	19	4	8	3	1	—	3	—	—
Plumbers	1	1	—	—	—	—	—	—	—
Potters Metal Workers.	2	—	1	1	—	—	—	—	—
Tinning &c.	3	1	1	—	1	—	—	—	—
Printers	2	1	—	—	—	—	1	—	—

Although the number of cases given in Table IV., which excreted lead in excess of 0.10, is far greater than those given in the above table as suffering from lead poisoning, there is every reason to believe that a number of these cases will in time show signs and symptoms of lead poisoning in addition to the excretion of an exeessive amount of lead. From the fact that the quantity of lead excreted by 24 of these cases is not greater than 0.10 mgm. per litre, it is clear that the excretion of lead in itself is not sufficient evidence to prove lead poisoning. In a normal person the amount of lead excreted is probably a measure of the amount of the lead intake, but when signs and symptoms of poisoning become apparent, the excretion then would appear to become some function of the efficiency of the kidney to eliminate lead.

The excretion of lead in a few cases of lead poisoning, who at the time of examination were not in employment, are given in the following table:—

Table VI.

Case No.	Nature of Work.	Date of last exposure to lead.	Date of examination.	Lead in urine. Mgm. per litre.	Remarks.
1	Motor Car Painter	—.11.24	30.4.25 20.7.25 27.1.26 29.1.26 13.7.26	0.02 0.03 0.02 0.02 0.01	
106	Sheet Metal Worker. Tinning	10.5.25	23.6.25 7.7.25 4.9.25 10.11.25 20.4.26 21.4.26 25.6.26 28.9.26 16.2.27 3.8.27	0.07 0.09 0.08 0.20 0.15 0.15 0.20 0.11 0.18 0.22	This man had had medical treatment by dieting and drugs for a long period.
107	Painter	23.8.25	24.8.25 9.9.25 17.9.25 1.10.25 3.3.26 26.3.26 9.9.27	0.50 0.12 0.25 0.15 0.08 0.05 0.30	Had returned to work.
121	Painter	7.5.26	14.5.26 26.7.26 11.8.26	0.12 0.37 0.20	
123	Lead Worker	7.6.28	8.6.26 27.7.26	0.53 0.13	Lead accumulator, pasting.
349	Lead Worker	12.12.26	4.1.27 24.3.27	0.15 0.12	Lead accumulator, mixing.
354	Lead Worker	24.1.27	25.1.27 8.4.27	0.40 0.18	Lead accumulator, filing.
359	Lead Worker	6.2.27	7.2.27 8.4.27	0.40 0.24	Lead accumulator, moulding.

It will be noticed, as in Case 107, that when exposure to lead has ceased, the amount of lead excreted at first rapidly decreased, and then more slowly, until approximately a constant figure is found. Subsequent variations in the amount of lead excreted would appear to depend very largely on the diet of the patient concerned. The

lead excretion of such a case is well shown in No. 106. This patient had not worked with lead since 10/5/25, and had been medically treated in an attempt to eliminate the lead stored in the body.

Urine Acidity and Lead Content.

In order to investigate the possible relationship between the acidity of a urine and its lead content, the re-action towards methyl red of a number of urines was determined immediately after excretion. The following table contains a summary of the results obtained, and gives the number of cases examined, the re-action to methyl red, and the lead content, in mgm. per litre, within the limits stated:—

Table VII.

Total No. Examined.	Reaction to m.red.	No. of Cases	Lead mgm. per litre. 0.00 0.05	0.06 0.10	0.11 0.15	0.16 0.20	0.21 0.25	0.26 0.50	0.51 1.00
	Acid	80	31	24	8	5	4	5	3
180	Neutral	25	15	5	2	2	—	1	—
	Alkaline	75	43	18	8	2	3	1	—

From a consideration of these results, it is evident that there is a tendency for urine, when acid, to have a higher lead content than when neutral or alkaline. This is most noticeable in those cases where the lead excretion is high.

Normal Lead Excretion.

It has been mentioned that the normal excretion of persons not associated with lead in any way other than through such agencies as food, etc., would appear to vary from 0.0.5 to 0.05 mgm. per litre. These figures are based on the analysis of the urine of a number of such persons, and also on some 200 analyses of the urine of one person whose lead excretion over a period of 3 years varied only within the limits stated.

Summary.

The ordinary methods of analysis are based on the formation of so-called insoluble salts, but all of these salts have a definite solubility, and, therefore, such methods are applicable only to the determination of quantities which are relatively large when compared with the amounts left in solution.

In the determination of lead in urine, the quantity present is very often as small as 0.02 mgm. per litre, or 1 part of lead in 50 millions of urine, and under such conditions the usual methods of analysis are of no value. To overcome this difficulty, the method given in this investigation has been devised, in which the lead is separated from accompanying salts by means of adsorption on calcium oxalate. This method has proved eminently successful, and by its use an amount of lead as small as 0.005 mgm. per litre of urine can be determined.

The results obtained from the examination of the urine from 330 cases are given in Table IV., and show that the amount of lead excreted generally corresponds with the degree of exposure to lead. In Table V. is summarised the lead excretions of 68 cases of lead poisoning, and from a consideration of these results it is at once seen that there is a very wide variation in the amount of lead excreted. It is shown that, when exposure to lead has ceased, the amount excreted rapidly decreased until approximately a constant figure is found.

From an examination of 180 specimens of urine, the acidity of the urine appears to be related to its lead content. It was found that samples which gave an acid re-action to methyl red contained on an average slightly more lead than neutral or alkaline ones. This was particularly noticeable in those cases which had a high lead excretion.

In putting forward this method for the determination of lead in urine, it is hoped that it will prove useful to those investigators who are interested in such problems, and that it may help towards the development of methods of analysis based on physico-chemical principles for the determination of minute quantities of the other metals.

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THE ESSENTIAL OIL FROM THE TIMBER OF ROSEWOOD (DYSOXYLON FRASERANUM).

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(Read before the Royal Society of New South Wales, Dec. 7, 1927.)

On the 6th December, 1922 (see this Journal, Vol. LVI., pages 233-240) Mr. M. B. Welch, B.Sc., A.I.C., Economic Botanist of the Technological Museum, described the examination of this timber, with a view to tracing the origin of the resinous exudation (so-called "sweating") which occurs with this species. He showed that the "sweating" was due to a volatile oleo-resin, and that a film of oil was noticed on the condensate in the carrying out of the moisture determinations.

Reference was also made to an experiment of the author, wherein 14lbs. weight of the shavings were subjected to steam distillation in order to afford confirmation of Mr. Welch's observations. An oil of a pale blue colour was obtained to the extent of 2.7% on the wet weight, and in view of the apparently interesting nature of the oil, it was deemed advisable to proceed further with its examination. A preliminary investigation of the oil showed it to consist essentially of sesquiterpenes, and accordingly a consignment of the timber was ordered, so that sufficient oil would be available for the work. The first two distillations of shavings made on behalf of the Economic Botanist were found to consist largely of cadinene, and not unlikely of copaene, with probably aromadendrene and a trace of azulene.

The largest and last lot of timber examined with a view to isolating cadinene in quantity from its hydrochloride was most curiously found not to contain this particular sesquiterpene, but a mixture of three others, which do not appear to have been observed previously.

The intensely dark blue colour of this last lot of oil was found to be due to azulene, present to the extent of 0.75%. The so-called "sweating" of the timber is undoubtedly due to the presence of this oil, and probably to the nature of the components, sesquiterpenes of variable physical properties, some readily resinifying, whilst others do so with difficulty.

The Essential Oil.

The oils varied in colour from a pale azure blue to a very intense dark blue in colour, the latter being similar to that of cupric ammonium sulphate. The oils were viscous, and possessed a bacon-like odour, and were obtained in a yield of from 1.3 to 2.7% on timber containing 41 to 46% moisture, equal to 1.6% to 3.42% on air-dried timber containing 12% moisture.

The main constituents identified were found to be a mixture of sesquiterpenes, possibly two, which are apparently hydroazulenes, as on dehydrogenation with sulphur the intensely blue hydrocarbon, azulene, is obtained, a third sesquiterpene yielding an inactive dihydrochloride of melting point 108-109°, for which the name Dysoxylonene is suggested. Cadinene was found to be one of the principal sesquiterpenes in the first two distillations. It is not unlikely that copaene is present as well. A sesquiterpene alcohol was also detected, but as it would not combine with phthalic anhydride it could not be isolated on account of the large quantity of sesquiterpenes present. The blue colour of the oils was found to be due to azulene, the well known blue

hydrocarbon. The naming of the principal sesquiterpenes from the large consignment of timber examined is deferred on account of the classic investigations of Ruzicka and his collaborators at present in progress on these important essential oil components. This investigator has recently examined azulene and its reduction products (see B.C. Abstracts, March, 1926, page 299), and as the sesquiterpenes isolated from rosewood yield azulene on dehydrogenation, it seems to be in the best interests of sesquiterpene chemistry for the name to remain in abeyance pending the completion of Ruzicka's investigations, as to do so at the present juncture might possibly lead to considerable confusion, which it is most desirable to avoid.

So far as the author is aware, these sesquiterpenes represent quite a new group, as, according to the investigations of Ruzicka and co-workers ("Helvetica Chimica Acta," 1922, 5, 345-368), most of the sesquiterpenes recorded in the literature yield on dehydrogenation with sulphur either one of the napthalene hydrocarbons, cadalin, or eudalin. The only previous record of a sesquiterpene yielding a blue oil on sulphurisation is that of Ruzicka (see Abstract in "Perfumery and Essential Oil Record," Vol. 14 (1923), page 411). It was obtained from one of the sesquiterpene fractions isolated from the oil of *Eucalyptus globulus*, and the blue oil yielded a black picrate melting at 122°.

Experimental.

603lbs. weight of shavings on steam distillation, under varying conditions, yielded pale to dark blue coloured oils, possessing the chemical and physical characters shown in table.

TABLE.

Date	Locality	Weight of Shavings.	%age Yield of Oil on wet wood	%age moisture in wood.	$d_{15}^{21.5}$	a_D^{20}	n_D^{20}	Solubility in 80% & 90% Alcohol. (by weight).	Ester No 1½ hours hot sap.	Ester No after Acetylation	Remarks
7/7/22	Chillingham. N.S.W.	12lbs.	1.3%	46.13%	0.930	−5°	1.5035	insoluble 10 vols.	2.2	47.2	Mostly red wood. Tree felled 28/4/1922. Wood received 4/7/'22. Distilled for 1½ working days.
11/7/22	,,	14 ,,	2.7%	41.87%	0.925	too dark to read	1.5036	do.	10.6	40.4	Red and white wood. Distilled for 6½ days.
21/11/23	Comboyne. N.S.W.	579 ,,	1.2%	41%	0.9398	do.	1.5046	do.	2.7	62.5	Distilled for 8½ hours at from 2 to 17lbs. per square inch.

It was very difficult to remove the whole of the oil, and microscopic examination of the shavings after steam distillation showed oil globules to be present,

100 c.c. crude oil, 11/7/1922, gave the following results on distillation over metallic sodium at 10 m.m.:—

No.	Fraction.	Volume.	$d\frac{1}{1}\frac{5}{5}$	a^{20}_{D}	n^{20}_{D}
1	112–128°	20 c.c.	0.9117	−4.95°	1.4990
2	129–130°	35 c.c.	0.9134	−2.9°	1.5020
3	131–135°	16 c.c.	0.9231	+3.35°	1.5057
4	136–140°	26 c.c.	0.9264	+4.2°	1.5067

Determination of Cadinene.

All the above-mentioned fractions yielded crystalline hydrochlorides on treatment with hydrochloric acid gas in dry ether solution at —20°, the yield gradually increasing from the first to the last fraction. The crude hydrochlorides were recrystallised from ethyl acetate when the crystals from fractions Nos. 1 to 3 melted at 117-118°, and from No. 4 at 118-119°.

0.3286-gram of the hydrochloride from fraction No. 1 dissolved in 10 c.c. chloroform gave a reading of +1.35°; $[a]^{20}_{D}$, +41.1°. 0.4352-gram of hydrochloride from fraction No. 4 dissolved in 10 c.c. chloroform gave a reading of −1.9°; $[a]^{20}_{D}$, −43.65°.

The oil apparently consists of a mixture of sesquiterpenes, in which cadinene or one yielding cadinene dihydrochloride preponderates. The lower boiling sesquiterpene might probably be aromadendrene with copaene.

The fractions on dehydrogenation with sulphur at 180-215° yielded a yellow hydrocarbon, which, without purification, possessed the following physical characters:—

B.pt. 150-155° (8 m.m.); $d\frac{1}{1}\frac{5}{5}$, 0.9881; n^{20}_{D}, 1.5510.

When treated with picric acid in alcoholic solution, it yielded an orange coloured picrate, which on purification from ethyl alcohol melted at 114-115°, identical with cadalin picrate recorded by Ruzicka. Azulene was not produced on dehydrogenation with sulphur. The sesquiterpene frac-

tions gave the usual characteristic colour reactions with bromine in acetic acid solution (violet crimson) and sulphuric acid in acetic anhydride (bright green changing to indigo blue).

500 c.c. crude oil, 21/11/1923, gave the following final results on repeated fractional distillation over metallic sodium at 10 m.m.:—

No.	Fraction.	Vol.	d_{15}^{15}	a_D^{20}	n_D^{20}	Remarks.
1	115–125°	28 c.c.	0.9000	+1°	1.4950	Did not yield a solid hydrochloride.
2	125–127°	14 c.c.	0.9107	+5.3°	1.4992	do.
3	127–130°	44 c.c.	0.9182	+8.75°	1.5027	do.
4	131–135°	70 c.c.	0.9247	+12°	1.5047	Crystalline hydrochloride formed.
5	135–138°	60 c.c.	0.9337	+13.6°	1.5060	do.
6	138–141°	60 c.c.	0.9333	+13°	1.5057	do.
7	Blue Oil	105 c.c.	0.9575	——	1.5068	do.
	Residue and loss.	balance.				

Determination of Sesquiterpenes.

The first three fractions on treatment with hydrochloric acid gas in dry ether solution at —20° did not yield any solid hydrochlorides. On dehydrogenation with sulphur at 180-215°, fraction No. 1 yielded but a trace of azulene whilst the accompanying hydrocarbon could not be identified, as it did not yield a crystalline picrate.

Fraction No. 3, on similar treatment, yielded 30% crude azulene, whilst fractions Nos. 4 to 6 inclusive gave 33% of that hydrocarbon on distillation from the reaction products at 2-3 m.m.

The crude azulene thus obtained possessed the following

B.pt. 140-145° (5 m.m.); d_{15}^{15}, 0.9835, and on treatment with picric acid in ethyl alcohol solution formed the characteristic picrate, which on recrystallisation from ethyl

alcohol separated as black needles melting at 118-119°. (Azulene picrate has been variously reported as melting from 118° to 122°.) (See Ruzicka and Rudolph, B.C.A., March, 1926, page 299.) The sesquiterpene fractions Nos. 3 to 6 inclusive gave very striking colour reactions on treatment with bromine vapour in acetic acid solution and sulphuric acid in acetic anhydride solution. The former yielded an intense indigo blue colour, whilst the latter gave a typical malachite green colour, changing finally to indigo blue.

In the course of the experiments to be related, which resulted in the preparation of a sesquiterpene dihydrochloride, the liquid hydrochlorides were separated and subjected to further examination. A portion was taken, cooled to —20°, and the small quantity of the solid hydrochloride which separated was removed by filtration through a Buchner filter funnel. 90 c.c. of the liquid hydrochlorides, 300 c.c. glacial acetic acid, and 80 grams of anhydrous sodium acetate were then heated together over a boiling water-bath for 4 hours, and the regenerated sesquiterpenes separated and purified by repeated distillation over metallic sodium.

The following fractions were subsequently obtained:—

Fraction.		Volume.	$d\frac{15}{15}$	a^{20}_{D}	n^{20}_{D}
120–128°	at 10 m.m.	10 c.c.	0.9126	+14.2°	1.4982
130–135°	do.	48 c.c.	0.9177	+ 0.4°	1.5040
135–137°	do.	10 c.c.	0.9251	— 6.6°	1.5070

All three fractions on treatment with dry hydrochloric acid gas in ether solution at —20° did not yield any crystalline derivatives. On the other hand, although it is obvious that two distinct sesquiterpenes were present, the middle one being a mixture of the two, all three fractions yielded azulene on dehydrogenation with sulphur at 180-220°.

Separation of Sesquiterpene Dihydrochloride.

The solid hydrochloride which resulted from the treatment of Fractions Nos. 4, 5, 6, and "Blue Oil," with dry hydrochloric acid gas in dry ether solution at —20°, was separated and purified by recrystallisation from ethyl acetate. It separated in well-defined crystals, melting at 108-109°—

(a) 0.1136-gram in 10 c.c. chloroform was found to be inactive.

The following experiments were carried out in order to obtain a sufficient quantity of this derivative for experimental purposes:—

(1) 100 c.c. crude oil, 21/11/23, was dissolved in 50 c.c. glacial acetic acid and dry hydrochloric acid gas passed in.
Yield 3.5 grams of crude hydrochloride.

(2) 100 c.c. crude oil, 21/11/23, was dissolved in 150 c.c. dry ether, and dry hydrochloric acid gas passed in at —20°. 7 grams crude hydrochloride were thus obtained.

(3) Same as No. 2; yield 7 grams of crude hydrochloride.

On recrystallising the total yield of hydrochloride from ethyl acetate, about 14 grams of pure material were obtained, melting at 108-109°. 1.0 gram dissolved in 10 c.c. chloroform was found to be inactive in polarised light.

(1) 0.2074 gram of hydrochloride on analysis according to the method of Piria and Schiff, gave 0.2114 gram AgCl=25.22% Cl.

(2) 0.2316 gram of hydrochloride gave 0.2396 gram AgCl=25.63% Cl.
$C_{15}H_{24}Cl_2$ requires 25.81% Cl.

Separation and Determination of Sesquiterpene from above Hydrochloride.

13 grams of the purified hydrochloride, 13 grams of anhydrous sodium acetate, and 43 c.c. glacial acetic acid were heated on a water bath for 4 hours, and the regenerated sesquiterpene separated and purified by steam distillation. It was obtained as a colourless liquid by distillation under reduced pressure.

It possessed the following physical characteristics:——

B.pt. 136-137° at 10 m.m.; d^{15}_{15}, 0.9236; α^{20}_{D} ±0; n^{20}_{D} 1.5063.

On addition of bromine vapour to an acetic acid solution of the sesquiterpene only a faint greenish colouration was produced, in striking contrast to the bluish purple colouration produced with the other sesquiterpenes present in the oil. An indifferent greenish blue colouration resulted on addition of a drop of sulphuric acid to its solution in acetic anhydride.

Only a few c.c. were available for experimental purposes, but on treatment with sulphur at 180-215° a small quantity of a pale yellow hydrocarbon was obtained, which yielded a brilliant orange red picrate on addition of an alcoholic solution of picric acid. It melted on recrystallisation from ethyl alcohol at 114-115°, and was thus identical with cadalin picrate. (See "Helvetica Chimica Acta," 1922, 5, pages 356-357.) The sesquiterpene is evidently related to the cadinene group. A search of the literature failed to reveal any sesquiterpenes of this character yielding an inactive dihydrochloride melting at 108-109°. It appears to be new to science, and the name Dysoxylonene is suggested for this constituent.

Determination of Azulene.

It was found that upon repeated fractional distillation of the crude oils that the blue constituent tended to concentrate in the higher boiling portion, the various sesquiterpene fractions varying in colour from almost water white to a pale yellow. Of the so-called "Blue" fraction, distilled at 143-148° at 10 m.m., 90 c.c. were taken, diluted with 200 c.c. petroleum ether (B. Pt. below 50), cooled to —10°, and 5 c.c. syrupy phosphoric acid (Sp. Gr. 1.75) added slowly, with frequent stirring, until the blue colour disappeared. The acid layer was subsequently separated, and the azulene regenerated by addition of water. The liberated azulene was again taken up in ether, washed with a solution of sodium bicarbonate, again with water, and finally with brine. After removal of the solvent, the azulene was obtained as a dark Prussian blue coloured viscous liquid. Its identity was confirmed by the preparation of the characteristic picrate, which melted sharply at 122°. A separate extraction of azulene from 100 c.c. of crude oil, 21/11/23, yielded 0.75 grams of crude hydrocarbon. The oil thus freed from azulene was of a bright brownish yellow colour.

Determination of Phenol.

100 c.c. crude oil on treatment with 8% sodium hydroxide solution gave 0.04 gram of liquid phenol, which yielded a brilliant red colouration with ferric chloride in alcoholic solution.

My thanks are due to Mr. F. R. Morrison, F.C.S., A.A.C.I., Assistant Economic Chemist, for much valuable help in this investigation.

PROOF OF THE LAWS OF TWIN-BIRTHS.

By Sir George H. Knibbs, C.M.G., M.Inst.Int.d.Stat., Hon.F.S.S., Hon.M.Amer.S.A., Hon.M.Stat.Soc.Paris, and of Hungary, etc.

(Read before the Royal Society of New South Wales, Dec. 7, 1927.)

SYNOPSIS. 1. Formulæ giving separately the relative numbers of uniovular and diovular twins. 2. Applicability to total twins. 3. Applicability to cases of two males, male and female, and two females. Limitations of the formulæ.

1. *Formulae giving separately the relative numbers of uniovular and diovular twins.* In an earlier paper, this Journal, Vol. 61, pp. 190-217, I showed that the frequency of twins born through the subdivision of a single fertilised ovum was sensibly the same for each age of the mothers, being always about 0.00300 of the cases of maternity. I showed, also, that the numbers born from two ova increased sensibly linearly up to age, say, 37 or 38, then decreased nearly linearly to the end of the child-bearing period (see formulae (2) and (2a), p. 200; and (3) and (3a), p. 202, this Journal). In formulae (3) the sign should be $+$. From this it is evident that the numbers for each age for the two types of cases can be given by the following type of formulae, in which t denotes the ratio of the number of twins to the number of cases of maternity:—

	Uniovular cases.	+ Diovular cases.
Up to age 37	$t=0.00300$	$+0.00058\ (x-15)$
Beyond age 37	$t=0.00300$	$+0.01276-0.00128\ (x-37)$

The constants of these formulae have been computed to fit approximately with few figures, the Australian results for the six years 1920 to 1925. The number for each age

of cases of maternity (mothers) on which these are based are given in Table VI., column (ii), pp. 197-8, of this Journal.

2. *Applicability to total twins.* In order to obtain a definitive idea of how these expressions do actually represent the data, the values of the two parts of *Ct* are given as against the data. In making the comparisons, however, it has to be remembered that the ages are merely *as stated* by the mothers (see remarks p. 191, this Journal). The actual ages probably differ slightly, for the ages are not given exactly.

Between the ages 12 and 49 inclusive there were 809,126 mothers (cases of maternity) and 8,403 cases of twins, viz., MM 2,792, MF 2,989, and FF 2,622. This would indicate that the probable number of uniovular cases was 2,792 + 2,622 — 2,989, that is 2,425. The calculated sum with the adopted approximate coefficient 0.00300, was 2,427.3.

It has already been shown (pp. 211-2 of this Journal) that this ratio is the same for each age during the child-bearing period.

Having regard to the number of cases, the rough formulae, given above, are seen from the table to represent closely the laws enunciated in the beginning of this paper, inasmuch as the observed and calculated results differ from each other for any one age, never more than — 32 and + 30 (ages 38 and 40 respectively), and the differences of the sums of these from age 12 upwards never disagree by more than — 58 to + 23 (ages 39 and 19 respectively).

The paucity of the numbers of cases suggests that it is not worth while attempting at present to furnish formulae of higher numerical precision.

The results thus established are:—(a) *three twins are produced, each from a single ovum, in every thousand cases*

Table I. Showing calculated and observed numbers of twins, for each age of mother from 13 to 49, and the sums of their differences.

Ages. i	Uniov. ii	Diov. iii	Calc. iv	Obsd. v	Diff. vi	Sum of Diff. vii
13	0.1	0.0	0	1	+ 1	+ 1
14	0.5	0.0	1	1	0	+ 1
15	1.5	0.0	2	3	+ 1	+ 2
16	6.3	1.2	7	11	+ 4	+ 6
17	17.1	6.6	24	22	— 2	+ 4
18	35.2	20.4	56	54	— 2	+ 2
19	56.4	43.6	100	121	+21	+23
20	75.2	72.7	148	134	—14	+ 9
21	96.6	112.1	209	205	— 4	+ 5
22	114.1	154.5	270	266	— 4	+ 1
23	129.5	200.3	330	337	+ 7	+ 8
24	138.5	240.9	379	349	—30	—22
25	142.2	274.9	417	437	+20	— 2
26	144.6	307.5	452	443	— 9	—11
27	141.9	329.2	471	469	— 2	—13
28	141.3	355.2	497	466	—31	—44
29	135.7	367.3	503	521	+18	—26
30	137.8	399.5	537	545	+ 8	—18
31	114.2	353.2	467	458	— 9	—27
32	116.0	381.3	497	486	—11	—38
33	103.2	359.0	462	483	+21	—17
34	96.2	353.3	450	456	+ 6	—11
35	86.9	336.1	423	419	— 4	—15
36	79.4	322.4	402	403	+ 1	—14
37	68.1	289.7	358	362	+ 4	—10
38	62.8	240.2	303	271	—32	—42
39	52.0	176.7	229	213	—16	—58
40	42.1	125.2	167	197	+30	—28
41	29.1	74.1	103	98	— 5	—33
42	25.0	52.9	78	84	+ 6	—27
43	16.9	28.7	46	41	— 5	—32
44	10.1	12.8	23	29	+ 6	—26
45	6.0	5.1	11	11	0	—26
46	2.7	1.1	4	6	+ 2	—24
47	1.3	—	1	0	— 1	—25
48	0.6	—	1	1	0	—25
49	0.2	—	0	0	0	—25

Column (iv) is the sum of columns (ii) and (iii) cast to the nearest unit. Column (vi) is column (v) less column (iv). Column (vii) is the algebraic sums of the figures in column (vi).

of maternity, whatever the age of the mother; and (b) *two ova are effectively fertilised* (i.e., result in living twins), *with a frequency increasing linearly with age till, say, age 37, but afterwards diminishing linearly till, say, about age 49* (or the end of the child-bearing period).

3. *Applicability of formulae to cases of two males, a male and a female, and two females.* In order to divide the calculated number of twins into MM, MF, and FF cases, it is necessary to know how the masculinity over all varies, if at all, with the age of the mother, and how the masculinity in uniovular cases compares with that of diovular cases.

It has already been shown in this Journal, sections 8 and 9 of former paper, p. 202, that the changes in masculinity are complex and irregular. Its general trend over all (m-f)/(m-f), see Table IX., may be approximately indicated by the following linear equations, viz:—

Ages 17 to 30; $\mu' = -0.0330 + 0.0074\ (x - 17)$.
Ages 30 to 38; $\mu' = +0.0632 - 0.0104\ (x - 30)$.
Ages 38 to 46; $\mu' = -0.0200\ +0.0046\ (x - 38)$.

The masculinity over all, however, is 0.02023, and is thus not very different from that of first-births, and of all births, since the former for 1921 to 1925 was 0.0278, and that for all births was 0.0250 (see Table IV., p. 195, and also column (viii.), Table VI., p. 197, this Journal).

While it will not be possible to compute exactly the MM, MF, and FF cases for each age, they can be closely approximated on the assumption that the masculinity over all, was for each age $\lambda = 0.02023$, and that the masculinity was $2\lambda = 0.04046$ for the MM and FF diovular cases, the former applying to the uniovular cases (see p. 203 of this Journal).

On the assumptions indicated we obtain from columns (ii.) and (iii.) in the preceding Table, the numbers of MM, MF, and FF cases. The respective results are:—

U;	Uniovular cases, age x,	$\frac{1}{2}U_x(1+\lambda)$		$\frac{1}{2}U_x(1+\lambda)$
D:	Diovular cases, age x,	$\frac{1}{4}D_x(1+2\lambda)$	$\frac{1}{2}D_x$	$\frac{1}{4}D_x(1+2\lambda)$
$U+D$;	Total cases, age x.	MM:	MF;	FF.

For example for age 37 we have from the tabular results, 68.1 and 289.7 in Table I., the following:—

	MM	MF	FF	Totals
Masc.* 0.0202; Uniovular	34.7	0.0	33.4	68.1
Masc.* 0.0405; Diovular	75.3	144.9	69.5	289.7
Masc. 0.0202; Totals	110.0	144.9	102.9	357.8
According to the data ...	105	148	109	362
Difference (obsd.-calc.) ..	—5	+3	+6	+4

The masculinities marked * are for the MM and FF cases alone. The discrepancies —5, +3 and +6 are not large considering the paucity in the number of cases.

Table II. below gives the calculated results for each age to the nearest whole number, and also the observed results, for the MM, MF, and FF cases; it discloses, therefore, how far the formulae, which are general, agree with the data. It will be seen that it establishes the fact that (c) *over the entire child-bearing period,* excepting, perhaps, say the first three or four commencing and closing years thereof, *the uniovular cases for each year of age are equal to the sum of the cases of two males and two females, less the cases of male and female.*

The measure of the goodness of fit of the formulae as representative of the data is not merely the closeness of the MM, MF, and FF individual results for each age, but also the aggregate of such results, viz., the sums of MM, MF, and FF up to each age. It is evident from the table giving these that the dictum is confirmed, viz., that the number of diovular cases increases sensibly linearly to age 37, and diminishes very nearly linearly afterwards. This is clearly the general law.

Table II. Showing Calculated and Observed Distribution of Twins, Australia, 1920 to 1925, for each age and their sums up to each age.

Mother's Age.	Ca. MM	Ob. MM	Ca. MF	Ob. MF	Ca. FF	Ob. FF	Ca. Sum MM	Ob. Sum MM	Ca. Sum MF	Ob. Sum MF	Ca. Sum FF	Ob. Sum FF
13 ..	0	0	0	0	0	1	0	0	0	0	0	1
14 ..	1	0	0	0	0	1	1	0	0	0	0	2
15 ..	1	1	0	0	1	2	2	1	0	0	1	4
16 ..	4	4	0	1	3	6	6	5	0	1	4	10
17 ..	11	8	3	4	10	10	17	13	3	5	14	20
18 ..	23	25	10	7	22	22	40	38	13	12	36	42
19 ..	40	39	22	33	38	49	80	77	35	45	74	91
20 ..	57	56	36	36	54	42	137	133	71	81	128	133
21 ..	78	73	56	42	74	90	215	206	127	123	202	223
22 ..	98	95	77	73	93	98	313	301	204	196	295	321
23 ..	118	120	100	99	112	118	431	421	304	295	407	439
24 ..	133	127	120	108	126	114	564	548	424	403	533	553
25 ..	144	149	137	144	136	144	708	697	561	547	669	697
26 ..	154	152	154	152	145	139	862	849	715	699	814	836
27 ..	158	152	165	166	149	151	1020	1001	880	865	963	987
28 ..	164	156	178	171	154	139	1184	1157	1058	1036	1117	1126
29 ..	165	171	184	192	155	158	1349	1328	1242	1228	1272	1284
30 ..	174	197	200	209	163	139	1523	1525	1442	1437	1405	1423
31 ..	150	145	177	170	141	143	1673	1670	1619	1607	1546	1566
32 ..	158	166	191	195	148	125	1819	1836	1810	1802	1694	1691
33 ..	146	154	179	185	137	144	1965	1990	1989	1987	1831	1835
34 ..	141	148	177	164	132	144	2106	2138	2166	2151	1963	1979
35 ..	132	128	168	172	123	119	2238	2266	2334	2323	2086	2098
36 ..	124	118	161	162	116	123	2362	2384	2495	2485	2202	2221
37 ..	110	105	145	148	103	109	2472	2489	2640	2633	2305	2330
38 ..	95	95	120	89	88	87	2567	2584	2760	2722	2393	2417
39 ..	72	62	88	97	68	54	2639	2646	2848	2819	2461	2471
40 ..	54	58	63	73	51	66	2693	2704	2911	2892	2512	2537
41 ..	34	33	37	33	32	32	2727	2737	2948	2925	2544	2569
42 ..	27	28	26	33	25	23	2754	2765	2974	2958	2569	2592
43 ..	16	11	14	18	15	12	2770	2776	2988	2976	2584	2604
44 ..	9	11	6	8	8	10	2779	2787	2994	2984	2592	2614
45 ..	4	3	3	5	2	3	2783	2790	2997	2989	2594	2617
46 ..	2	2	1	0	1	4	2785	2792	2998	2989	2595	2621
47 ..	1	0	0	0	0	0	2786	2792	2998	2989	2595	2621
48 ..	1	0	0	0	0	1	2787	2792	2998	2989	2595	2622
49 ..	0	0	0	0	0	0	2787	2792	2998	2989	2595	2622

Why there should be this sudden change after age 37, in the frequency of the effective fertilisation of two ova, is not apparent. The changes in the frequency of mater-

nity, column (ii.), pp. 197-8, of this Journal, throw no light upon it; and so far as the writer is aware, there are no other related statistical progressions which give any indication of a possible cause.

4. *Limitations of the formulae.* Obviously, it is practically certain that the number of uniovular cases is not represented by $0.00300C$ at the very beginning and end of the child-bearing period, although otherwise it is sensibly constant throughout. This needs investigation with a much larger number of cases. It also seems probable that the straight lines, representing the changes of frequency with age, are terminated by short curves concave upwards, and also that the two lines are joined by a curve convex upwards. To determine whether these are so or not, also requires as data a far larger number of cases. So far as I am aware, the necessary data are not yet available. It is to be hoped in future the ages of the mothers can be more accurately ascertained. An examination of the data will show that the numbers attributed to certain ages should probably be assigned to adjoining ages.

Melbourne, 19th November, 1927.

W—December 7, 1927.

SOME MECHANICAL PROPERTIES OF AUSTRALIAN GROWN PINUS INSIGNIS (P. RADIATA).

WITH NOTES ON THE WOOD STRUCTURE.

By M. B. Welch, B.Sc., A.I.C., Technological Museum.

(With Plates VII.-XI. and two text figures.)

(Read before the Royal Society of New South Wales, Dec. 7, 1927.)

Pinus insignis, Douglas, (or more correctly *P. radiata*, Don, although the former name has come into almost general use), is popularly regarded as a timber of comparatively little value. The prejudice is apparently due to the fact that trees grown in the open naturally possess numerous lateral branches and the timber is therefore knotty. Apart from this, however, it is commonly believed in Australia that the wood is devoid of strength, but the criticism is usually from those who have not had the opportunity of actually testing the wood. A few years ago, through the courtesy of the Forestry Commission of New South Wales, arrangements were made to obtain some of the timber from Gosford and Sutton Forest, New South Wales, from Creswick, Victoria, and from Wirrabara and Mt. Gambier, South Australia, in order to conduct a series of mechanical tests.

Pinus insignis is a native of the west coast of California and Sargent[1] states that the distribution is only along a narrow belt a few miles wide on the Californian coast from Pescadero to the shores of San Simeon Bay, and on certain islands off the coast. He states that it is a tree 80-100 ft.

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[1] Sargent, C. S. Manual of trees of North America. London, 1905.

in height with a tall trunk 2-3 feet but occasionally 5-6 feet in diameter, and describes the wood as being "light, soft, not strong, brittle, close-grained and occasionally used for fuel."

Some mechanical tests have been made previously, chiefly on South Australian material, the following being a summary of the results obtained for transverse tests.

Chapman[1], in a single test on beam about 6 feet in length, showed a modulus of rupture of 3504 lbs. per sq. inch, and later[2] gave a mean modulus of rupture on 35 tests of 6856 lbs. per square inch, with 11 per cent. moisture and with a similar span.

He summarises the results of his tests as follows:—"*Pinus insignis* has been commonly regarded as a rather poor timber, but the results show that its strength compares quite well with that of Oregon. It is not quite so good as a beam, though the difference is not very great, but it has a greater resistance to splitting and shearing along the grain, and it is less easily compressed across the grain. It is quite a useful timber for structural purposes."

Approximately similar results were given in a later bulletin.[3]

In a report to the Tasmanian Forestry Dept. in reference to *Pinus insignis* sent to the recent British Empire Exhibition, the following figures were given as the result of tests made at the University of Tasmania. Beam, 2 inches wide x 6 inches x 8 feet, modulus of rupture (mean of two tests) = 6.12 tons, as against 5.14 tons for oregon (mean

1 Chapman, R. W. The Strength of South Australian Timbers, Trans. Roy. Soc. S. Aus. xxxii, 1908.

2 Chapman, R. W. Physical Properties of some South Australian grown Pines, Trans. Roy. Soc. S. Aus. xliii, 1919.

3 Chapman, R. W. The Strength of South Australian Timbers. Bulletin No. 9, Dept. of Forestry, University of Adelaide, 1922.

of three tests), the moisture contents being 14.0 per cent. and 13.1 per cent. respectively.*

Daugherty[1] in a description of the xylem of *Pinus radiata* makes the following statement, in reference to the American naturally grown wood. "The wood is light, rather soft, not strong, brittle and as a rule, close grained and compact." He quotes Penhallow[2] as giving the following data: Specific gravity = 0.4574, ultimate transverse strength in kilograms = 316 00. The latter figure is incomplete, but if per sq. cm., is probably equivalent to a modulus of rupture of 4490 lbs. per square inch.

The following transverse tests were made on air-dry specimens, 2in. x 2in. x 24in. span with centre load, on a 25 ton Riehle machine. In order to obtain comparative results, only clear specimens were used, and a number of tests were discarded in which failure could obviously be attributed to knots or other defects.

GOSFORD, NEW SOUTH WALES.

Tree grown at sea level in sandy soil; average rainfall 49 inches; age uncertain. Log 8ft. long, maximum girth 3ft. 4in., centre 2ft. 10in., minimum 2ft. 7in.

Number of tests = 17.

		f	E	W	M%	r.p.i.	L.W.%
Max	=	11,475	1,317,000	42.6	14.9	6	30
Min.	=	7,335	659,000	30.6	13.4	2	15
Mean	=	9,450	965,000	39.1	14.1	4	23

* Eckbo in Bull. No. 19, Forest Dept., South Africa, gives the following values:—F = 12,780, E = 2,116,000, sp. gr. = 0.55, M = 9.6%, as the mean of 18 tests on South African grown Pinus insignis.

1 Daugherty, L. H. Anatomical description of the xylem of Pinus radiata in MacDougal, D. T. Reversible variations in volume, pressure and movements of sap in trees. Carnegie Institute Publication, Washington, 1925.

2 Penhallow, D. P. North American Gymnospems, Boston, 1907. Unfortunately, a copy of this book is not available in Sydney.

The figures given above are the maxima and minima under each heading, the following are the figures actually corresponding to the maximum and minimum modulus of rupture, for the individual specimen.

	f	E	W	M	r.p.i.	%L.W.
Actual max. =	11,475	1,317,000	40.8	14.3	4	25
Actual min. =	7,335	659,000	30.6	13.9	2	15

Taking into consideration the varying rates of growth of the wood and the strengths at different densities, the following figures are obtained:—

r.p.i.	No. of tests	f	E	W	M%	L.W. %
2-2½	3	9,090	911,000	35.9	13.9	18
3-3½	2	9,520	816,000	38.8	14.4	18
4-4½	8	9,665	999,000	39.8	14.2	24
5-6	4	9,235	1,015,000	40.3	13.9	28

W	No. of spec.	f	E	M%	r.p.i.	L.W.%
30-32	1	7335	659,000	13.9	2	15
32-36	No specimen.					
36-38	4	9540	904,000	14.0	3½	19
38-40	4	9640	1,026,000	14.5	4	25
40-42	7	9490	990,000	13.9	4½	26

SUTTON FOREST, NEW SOUTH WALES.

Tree grown at about 2,000 feet elevation; average rainfall 35 inches, age, 35 years; height, 50 feet. Log cut 12 feet from butt, maximum girth 3 feet 11 inches; minimum girth 3 feet 6 inches; length, 9 feet. Number of tests, 27.

* f = Modulus of Rupture in lbs. per sq. in.

E = Modulus of Elasticity in lbs. per sq. in.

W = Weight per cubic foot in lbs. at time of testing (air-dry volume).

M% = Percentage of moisture at time of testing, calculated on the dry weight.

r.p.i. = Average number of growth rings per inch.

L.W.% = Percentage of growth rings consisting of late or summer wood.

	f	E	W	M%	r.p.i.	L.W.%
Max. =	11,700	1,728,000	35.3	15.3	7	30
Min. =	7,430	864,000	28.3	13.0	2	7
Mean =	9,710	1,344,000	31.7	13.9	3.5	19
Actual max. =	11,700	1,455,000	35.3	13.5	7	30
Actual min. =	7,430	891,000	28.3	14.1	2	7

r.p.i.	No of tests.	f	E	W	M%	L.W.%
2	5	7,430	924,000	29.7	14.1	10
2½	6	9,560	1,185,000	30.2	13.9	18
3	4	9,840	1,487,000	32.4	14.1	18
3½	3	9,840	1,392,000	31.0	13.9	19
4	2	10,730	1,556,000	34.0	13.8	22
4½	2	10,280	1,537,000	33.1	13.5	22
5	5	10,760	1,526,000	32.5	13.6	24
7	1	11,700	1,455,000	35.3	13.5	30

W	No of tests.	f	E	M%	r.p.i.	L.W.%
28-29	4	8,300	956,000	13.9	2	11
29-30	No specimen.					
30-31	4	9,190	1,275,000	14.3	3	15
31-32	7	9,730	1,378,000	13.9	3½	21
32-33	7	9,990	1,441,000	14.0	3½	19
33-34	1	10,220	1,455,000	13.5	3	15
34-35	2	11,230	1,496,000	13.9	5	25
35-36	2	11,630	1,592,000	13.9	5½	30

CRESWICK, VICTORIA.

Trees grown on heavy clay soil intermixed with gravel, age about 26 years; altitude 1,650 feet; average rainfall 26 inches; sawn timber supplied. Number of tests = 13.

	f	E	W	M%	r.p.i.	L.W.%
Max. =	12,510	1,728,000	37.9	15.2	8	25
Min. =	6,615	768,000	29.9	12.7	4	15
Mean =	9,990	1,453,000	34.0	13.9	5½	21
Actual max. =	12,510	1,627,000	37.4	13.6	4½	25
Actual min. =	6,615	768,000	31.9	13.4	4½	20

r.p.i.	No. of tests.	f	E	W	M%	L.W.%
4	4	9,900	1,500,000	32.4	14.0	18
4½-5	3	9,380	1,283,000	33.6	13.4	22
5½-6	3	10,360	1,494,000	34.9	14.5	21
6½-7	2	10,330	1,440,000	35.3	13.7	22
8	1	10,450	1,515,000	37.5	13.7	25

W	No. of tests.	f	E	M%	r.p.i.	L.W.%
28-30	1	7,705	1,383,000	15.2	4	15
30-32	5	9,310	1,386,000	14.0	4½	19
32-34	1	9,315	1,152,000	14.4	7	20
34-36	1	8,860	1,290,000	14.0	6	25
36-38	5	11,565	1,627,000	13.5	6	22

MT. GAMBIER, SOUTH AUSTRALIA.

Tree grown under forest conditions about 9 feet apart, on volcanic soil; age about 45 years; diameter breast height over bark, 15 inches; log cut 16 feet from butt. Number of tests = 26.

	f	E	W	M%	r.p.i.	L.W.%
Max. =	10,395	1,537,000	31.2	17.8	5½	25
Min. =	5,875	553,000	26.0	13.0	1½	10
Mean =	8,280	1,113,000	29.2	14.3	3	17
Actual max. =	10.395	1,537,000	31.2	14.4	2½	20
Actual min. =	5,875	553,000	26.0	14.8	1½	18

r.p.i.	No. of tests.	f	E	W	M%	L.W.%
1½	5	6,930	709,000	27.1	14.9	13
2	5	7,215	819,000	27.7	13.9	18
2½	2	9,270	1,281,000	30.2	13.7	16
3	4	9,250	1,245,000	30.3	14.6	18
3½	2	9,650	1,292,000	30.7	14.2	16
4	2	9,440	1,383,000	30.6	13.9	23
4½-5	2	8,595	1,397,000	31.2	14.7	20
5½-6	2	9,000	1,419,000	29.4	14.6	18

W	No. of tests.	f	E	M%	r.p.i.	L.W.%
26-27	4	6,460	640,000	14.9	1½	12
27-28	6	7,590	914,000	14.0	2½	15
28-29	1	8,595	1,024,000	13.8	3	15
29-30	1	8,145	1,024,000	13.9	2½	12
30-31	6	9,340	1,349,000	14.5	4	20
31-32	6	9,405	1,369,000	14.3	4	20

WIRRABARA, SOUTH AUSTRALIA.

Tree grown under forest conditions, original spacing 8 feet, increased to 20 feet by thinning; grown on good to fair sandy loam; age 45 years; diameter breast height over bark 14 inches. Number of tests = 32.

	f	E	W	M%	r.p.i.	L.W.%
Max. =	11,745	1,875,000	32.0	15.7	6½	20
Min. =	7,110	767,800	26.5	13.1	4½	7
Mean =	9,010	1,278,000	29.8	14.1	6	12
Actual max. =	11,745	1,152,000	30.6	13.8	6½	20
Actual min. =	7,110	813,000	27.0	13.5	6½	8

r.p.i.	No. of tests.	f	E	W	M%	L.W.%
4½	3	7,800	1,114,000	27.3	14.7	9
5	4	9,665	1,390,000	31.5	14.0	12
5½	5	9,485	1,305,000	30.5	14.2	10
6	7	9,325	1,250,000	29.9	13.9	12
6½	9	8,580	1,314,000	27.7	14.1	12

W	No. of tests.	f	E	M%	r.p.i.	L.W.%
26-27	2	7,860	1,277,000	13.5	5½	10
27-28	9	8,135	1,195,000	14.5	6	12
28-29	No specimens.					
29-30	3	9,405	1,363,000	13.8	5½	12
30-31	6	9,705	1,315,000	13.6	6	12
31-32	9	9,640	1,318,000	13.9	5½	12

*Impact Tests**.

The following Izod impact tests were made according to the British Engineering Standard Association specification for aircraft material.

Gosford, New South Wales.

	Energy absorbed in Foot-lbs.	M%	r.p.i.
Maximum	34.5	11.8	6
Minimum	14.5	11.7	2.5
Mean (14 tests)	22.9	11.9	3.5

Moisture content varied from 11.7-12.2; rings per inch 1½-6.

Sutton Forest, New South Wales.

	Foot-lbs.	M%	r.p.i.
Maximum	25.5	11.9	5
Minimum	4.5	11.9	2.5
Mean (14 tests)	15.3	11.7	3.6

Moisture content 11.1-12.4; rings per inch 1½-6.

Creswick, Victoria.

	Foot-lbs.	M%	r.p.i.
Maximum	23	—	4
Minimum	2	10.8	2
Mean (14 tests)	12.1	11.0	5.1

Moisture content 10.7-12.0; rings per inch 2-9.

* For comparison the following figures are given; they are included among others in a report by the late Professor W. H. Warren on timbers for aeroplane construction, and were published in the Australian Forestry Journal, V. 1922, p. 52.

		Energy of rupture Foot-lbs.	M%	W
Ceratopetalum apetalum,	Coachwood	11.8	13.1	44.1
Araucaria Cunninghamii,	Hoop Pine	4.8	12.7	34.6
Elæocarpus grandis,	Blue Fig	3.8	11.2	33.2
Flindersia Schottiana,	Cudgerie	14.3	11.4	46.8
Eucalyptus Delegatensis,	Alpine Ash	12.0	15.2	39.4
Eucalyptus fraxinoides,	White Ash	11.3	15.9	46.7

Mt. Gambier, South Australia.

	Foot-lbs.	M%	r.p.i.
Maximum	38	—	3.5
Minimum	8.5	10.7	1.5
Mean (17 tests)	18.4	10.9	2.5

Moisture content 11.1-12.4; rings per inch 2-6.

Wirrabara, South Australia.

	Foot-lbs.	M%	r.p.i.
Maximum	22.5	11.2	3
Minimum	2	—	4.5
Mean (13 tests)	14.9	11.9	40

Moisture 11.2-12.5; rings per inch 3-5.

The modulus of rupture as the result of static bending tests reached a maximum of 12,510 lbs. per sq. inch in material from Creswick, and a minimum of 5,875 lbs. per sq. inch in material from the Mt. Gambier. The mean figures are comparatively even, with the exception of Mt. Gambier 8,280 lbs. per sq. inch, which is rather low; the maximum of 9,990 lbs. per sq. inch was obtained in tests from Creswick. Since these tests were made on comparatively small logs, in which the relative amount of the weak inner wood was high, it seems evident that the mean tests made on larger trees with a higher percentage of mature timber would show an increased strength. The mean moisture contents were in the vicinity of 14%.

The modulus of elasticity, which is a measure of the stiffness of the wood, reached a maximum of 1,875,000 lbs. per sq. inch in Wirrabara material and a minimum of 553,000 lbs. per sq. inch in wood from Mt. Gambier. The mean figures showed a minimum in the tough, flexible wood from Gosford of 965,000 lbs. per sq. inch, and a maximum of 1,453,000 lbs. per sq. inch in Creswick specimens.

The impact figures indicate the ability of the wood to absorb energy, and are an indication of its toughness.* A wood which has a small ability to resist shock is regarded as brittle or brash, or in other words lacks toughness. This latter property is obviously extremely useful, since for many purposes for which wood is used, it is subjected to sudden loads, and a brittle wood is quite unsuitable. In general, coniferous woods are regarded as being less tough than porous woods[1], but a comparison with the figures given for a few Australian woods shows that *Pinus insignis* stands remarkably high; the mean figure for the energy absorbed is 16.7 foot-lbs. for all tests, with a mean weight per cubic foot of 32.8 lbs.

The minimum figure obtained for the Gosford material was 14.5 foot-lbs., and altogether this wood showed remarkable toughness. In the static bending tests it also proved itself the reverse of brittle, the test pieces often refusing to break after failure, and still carried a load little below the ultimate with a deflection of several inches. The ability to "hang on" after failure far exceeded any other wood of which I have had experience.

As might be expected the material cut from near the heart usually proved to be weak, this accounting for the considerable variation between the maxima and minima. Usually, but not always, wood which gave low figures under static bending tests gave comparatively low results for the impact tests.

Growth Rings.

The rate of growth, indicated by the number of growth rings per inch, appears to have some influence on the

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* The toughness of a wood is also indicated by the "work to maximum load" in static bending tests.

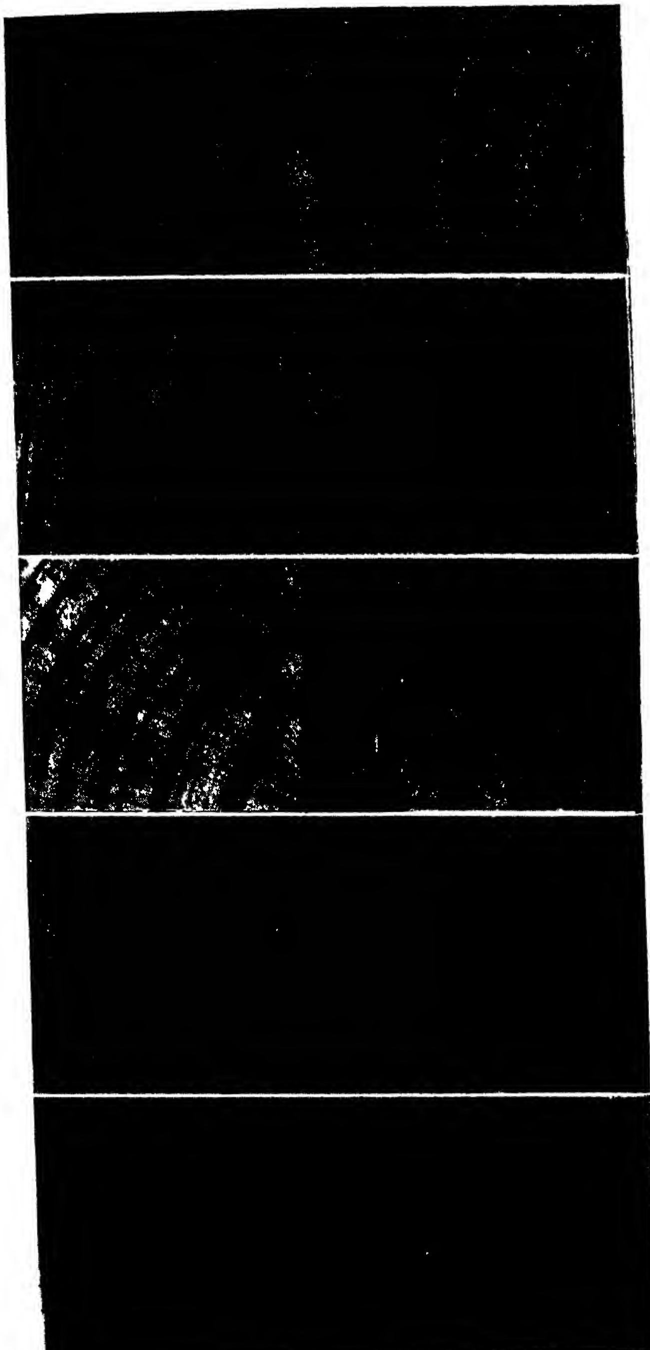
[1] Koehler, A. The properties and uses of Wood. New York, 1924.

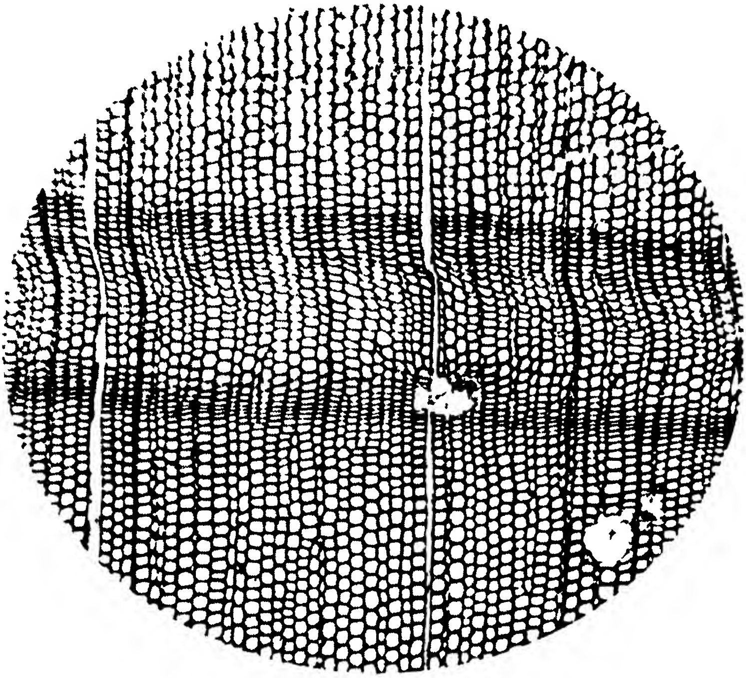
strength. Thus an examination of the mean test figures given for the different number of rings per inch, shows that in general, the more slowly grown wood is strongest, though here and there exceptions occur. It is obvious, however, that rate of growth in itself cannot have any direct influence on the strength of a coniferous wood, except in its effect on the thickness of the cell wall, or on the proportion of late wood in the growth ring. The accurate counting of rings was made difficult by the presence of numerous false rings, especially in the regions of slowest growth.

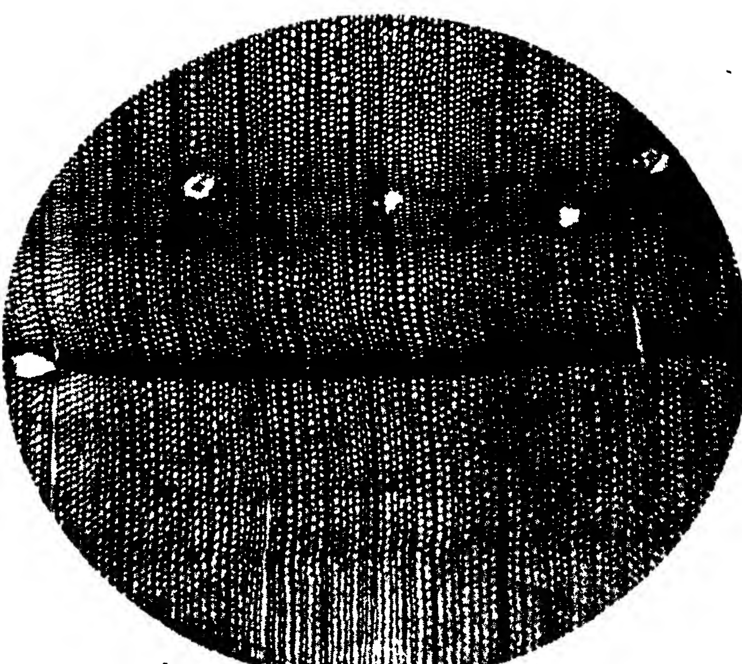
There appears to be no definite relationship between rate of growth and toughness as shown by the impact tests. Thus a test piece from Creswick with nine rings per inch broke at 5 foot-lbs., whereas a piece with 3 r.p.i. absorbed 21 foot-lbs.; similar exceptions occurred in the woods from other localities; as with the transverse tests, however, the weakest wood was usually near the centre.

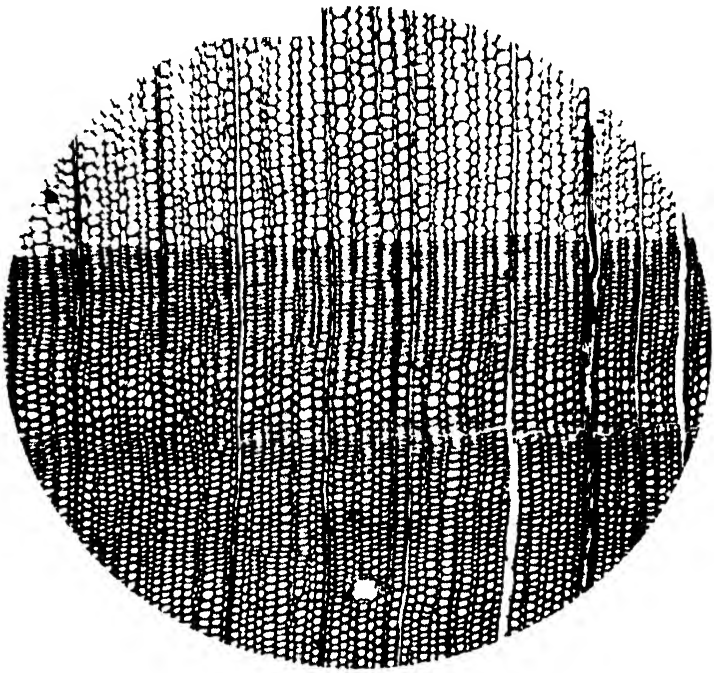
The Gosford log indicated rather uneven growth, Pl. VII. (a) and false rings were very pronounced. Material from Sutton Forest, Pl. VII. (b) showed considerable variation, near the centre the rings being two per inch, whilst near the bark the rate was slowed down to at least thirty per inch. The growth rings in the Creswick material, Pl. VII. (c), were well defined and fairly even, the increased spacing nearer the outside being due possibly to thinning. Mt. Gambier, Pl. VII. (d), showed rapid growth with false rings common near the main late wood. Wirrabara was particularly even in its growth, the average number of rings per inch in the transverse test specimens varying only from 4½-6½. The evenness of the growth is clearly shown in the illustration. Pl. VII. (e).

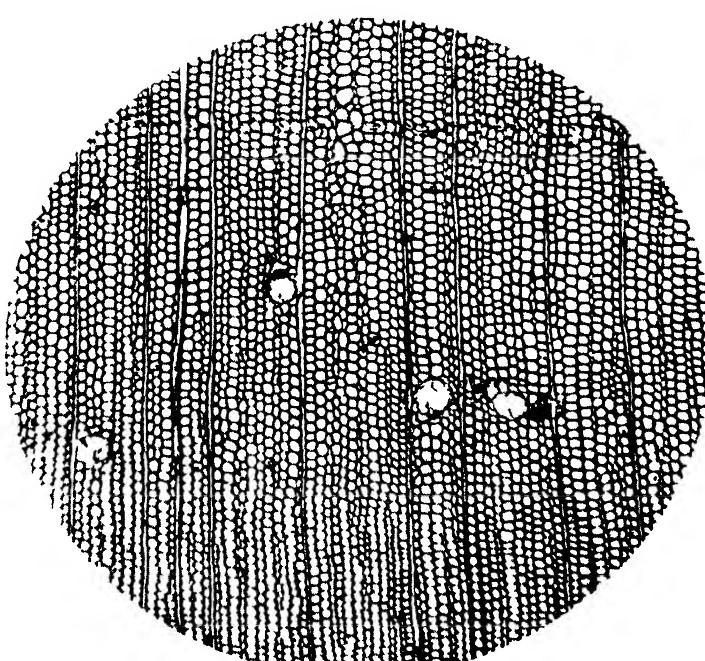
The percentage of late or summer wood in the growth ring is important in its influence on the strength of the wood, and an examination of the figures given for the actual











maxima and minima shows the weaker specimen to be that with the lesser late wood. The variations in the amounts of late and early wood are clearly seen in Pl. VII., the denser growth of the Gosford wood being very evident, whereas the South Australian material obviously contains more spring or early wood.

Weight.

The weight per cubic foot was found to vary considerably, the extreme figures being 26.1 and 42.6 lbs. In the log from Gosford a variation occurred of from 30.6 to 42.6 lbs., the outer more slowly grown wood being very dense, whereas that near the heart was much lighter in weight. The South Australian grown wood was much more even, the range being 26.0-32 lbs. per cubic foot. All figures given are calculated on the air dry volume at time of testing, with a moisture content ranging from 12-15%, the actual moisture percentage being shown

Apart from the figures already given in the introduction, King[1] records a minimum figure on wood grown at Tokai, South Africa, of 24.3 lbs. per cubic foot oven dry, which is equivalent to about 27.2 lbs. at 12% moisture, and further gives as a mean of about 20 tests an oven dry figure of 30.6 lbs., equal to 34.3 lbs. per cubic foot at 12% moisture, oven dry volume.

From the figures given for the transverse bending tests it is apparent that the weight has a considerable influence on the strength, the modulus of rupture usually increasing in proportion to the weight. The exceptions to this are not numerous, and are evidently caused by other factors, affecting one or two test pieces; with a larger series of tests the results would in all probability show an even closer relationship between strength and weight.

[1] King, N. L. *Pinus insignis* Doug. in South Africa. Forest Dept. South Africa, Bull. No. 15, 1925.

Comparing the mean strengths and weights, we have:—

	f	W
Gosford	9450	39.1
Sutton Forest ..	9710	31.7
Creswick	9990	34.0
Mt. Gambier	8280	29.2
Wirrabara	9010	29.8

Taking into consideration the weight, the Gosford wood should be far stronger than that from Sutton Forest or Creswick, yet the latter shows the maximum average.

Tracheids.

It is obvious that one of the principal factors affecting the mechanical properties of a timber are the thickness of the cell walls and the size of the cells. The following figures give the radial diameter of the tracheids in the early and late wood, and also the radial thickness of the cell walls. The radial diameters were obtained by counting the number of tracheids in 0.40 mm., and are not the maximum or minimum sizes of individual cells. The thickness of the cell walls is given as a range, in the early or late wood near the junction of the two.*

Thickness of cell walls.

	Early Wood.	Late Wood.
Gosford	3-6μ	6-13μ
Sutton Forest ..	2-4μ	5-10μ
Creswick	2-5μ	2-11μ
Mt. Gambier	1.5-4μ	4-9μ
Wirrabara	2-4μ	5-11μ

The greatest development of secondary thickening occurred in the Gosford wood, ranging up to 13μ in the late wood; the Creswick material was rather variable in the thickness of the cell wall, especially in the late wood. In

* Daugherty, l.c., gives the thickness of the tracheid walls as 2-3μ in the early wood and 4-7μ in the late wood.

general the wood near the pith showed less thickening in the late wood, though little variation was noticed in the early wood.

Radial diameter of Cells.

	Early Wood.	Late Wood.
Gosford	28-46μ	17-34μ
Sutton Forest ..	37-57μ	19-26μ
Creswick	34-53μ	18-31μ
Mt. Gambier	41-53μ	18-28μ
Wirrabara	37-62μ	17-26μ

The cells, which are naturally larger in the early wood, were smallest in the Gosford wood. The same wood also has the smallest cells in the late wood, and this, combined with the greater thickness of the walls, accounts for the greater density of the wood.

*Wood Structure.**

Macroscopic characters.—Sap-wood pale coloured, broad, heart-wood pale brown, not sharply defined. Growth rings well defined, but junction of late and early wood not always definite. Resin canals easily visible on end or longitudinal faces, brown in colour, most numerous and prominent in Gosford material and least in South Australian wood.

Gosford wood tough and leathery to work. South Australian wood, mild and easily worked. Sutton Forest and Creswick intermediate between the two. Creswick sap-wood had been attacked by a sap-stain fungus.

Microscopic characters.—Tracheids irregularly polygonal or somewhat rounded in section, radial diameter 14-88μ, tangential diameter 15-63μ; length—Gosford, inner wood 1.2-3.2 mm., outer wood 1.0-4.8 mm.; Sutton Forest i.w. 1.2-3.4 mm., o.w. 1.12-5.72 mm.; Creswick i.w. 1.12-2.8 mm.,

* Daugherty, l.c., has given a very complete description of the xylem of *P. insignis*.

o.w. 1.6-4.8 mm.; Mt. Gambier i.w: 1.24-3.0 mm., o.w. 1.28-5.32 mm.; Wirrabara i.w. 1.04-3.6 mm., o.w. 1.2-5.2 mm.† Cells usually fusiform, ends occasionally blunted and irregular (Text Fig. 1). Radial bordered pits usually oval, in single row, scattered, occasionally appressed, rarely opposite, 10-30μ in diameter; pit openings circular to elliptical, often opposed, 3-6μ in diameter. Tangential bordered pits rare except in late wood. Bars of Sanio not observed.

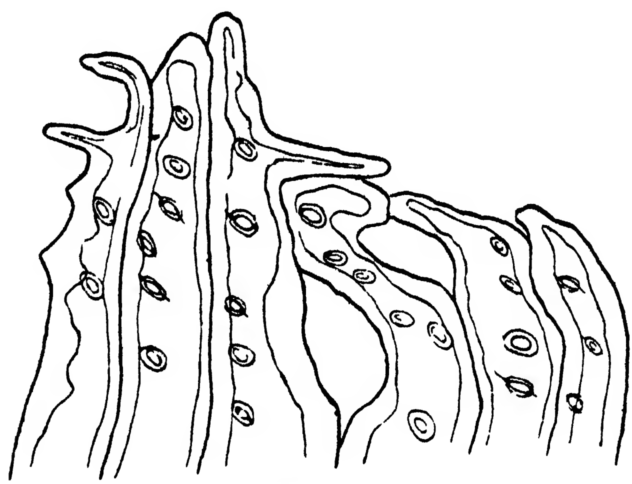
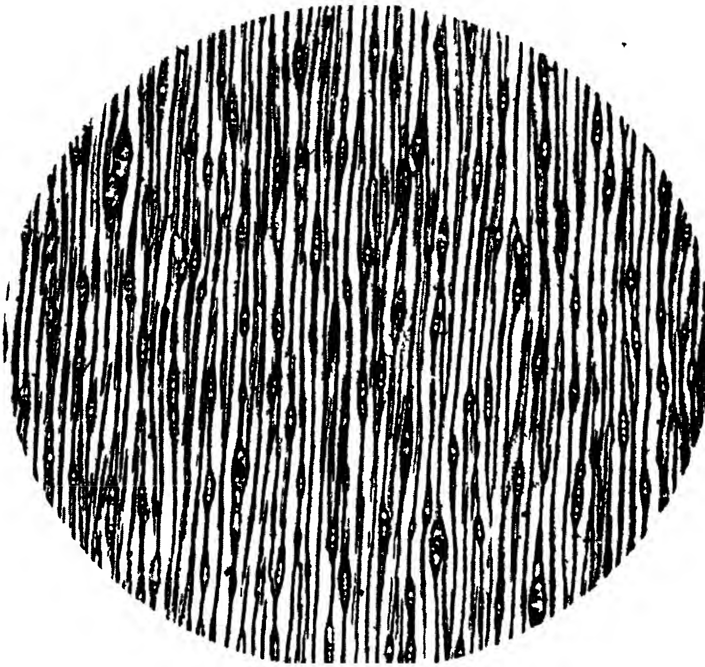
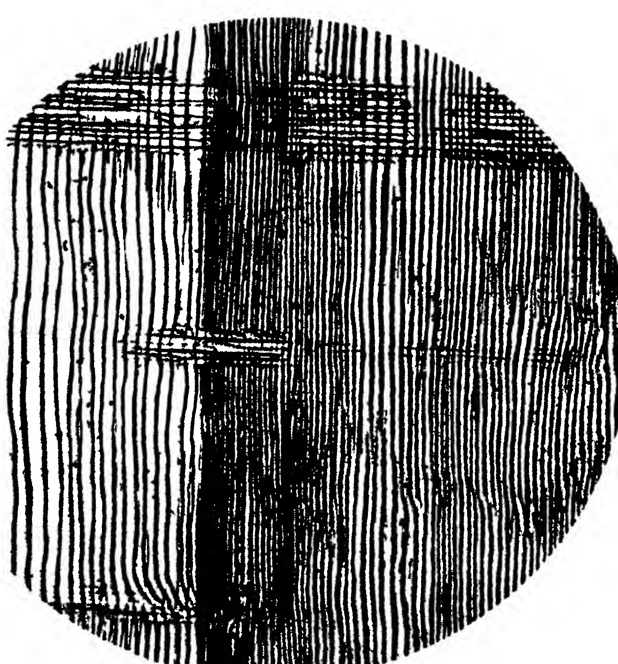


Fig. 1. Irregular tracheid ends

Rays uniseriate, 1-16 cells in height, or broad, fusiform with horizontal resin ducts. Ray parenchyma cells up to 450μ in length and 15-40μ in height; ray parenchyma-tracheid pits irregularly oval to narrow elliptical, usually one to three, rarely five, per section of tracheid, border narrow. Ray tracheids with "dentate" thickenings on inner walls (Text Fig. 2), commonly a ray may have one to three rows of tracheids at each edge or the distribution may be uneven, thus a ray may have as many as seven rows of

† Daugherty gives the following tracheid dimensions; radial diameter 13-68μ, tangential diameter 13-62μ, length 628-4150μ. It will be noted that the tracheid lengths of the mature wood of Australian grown *P. insignis* exceed these figures.





tracheids with a few rows of parenchyma cells, and again one or two rows of tracheids at the opposite edge, or the tracheids may occur in the middle of the ray; rays up to five cells in height were noted, consisting entirely of ray tracheids. The degree of reticulation varies considerably, and was most prominent in Gosford wood. Ray tracheid bordered pits small, usually less than 6μ in diameter. Small globules of an oily nature are numerous in the ray parenchyma cells; not observed in the tracheids or ray tracheids. Vertical resin passages chiefly in later part of early wood, although they are distributed throughout the growth ring (see Pl. VII.), cavity up to 150μ in diameter; tyloses oc-

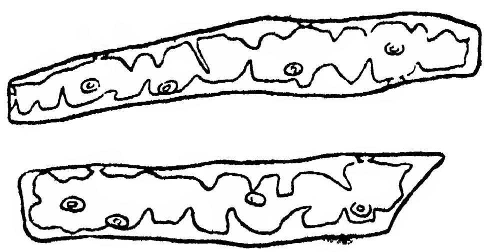


Fig. 2.
Ray tracheids showing reticulated thickening of inner Walls.

casionally present; epithelial parenchyma cells thin walled. Late wood very variable, from narrow bands 70μ in width in South Australian wood to several mm. in the denser Gosford material. False rings common.

Summary

The results of the tests show that some variation in density and strength occur in the wood grown under different conditions, but even the lightest and most rapidly grown material possesses considerable strength, and where more slowly grown, may possess remarkable toughness. There is evidently a fairly definite relationship between rate of growth, weight and strength. Apart from the wood near the heart, there is no justification for the belief that the

timber is brittle. The presence of reticulated thickenings on the inner walls of the ray tracheids places it in the yellow or pitch pine group.

I am indebted to the Mechanical Engineering Department, Sydney Technical College, and to Wing Commander Wackett, R.A.A.F., Experimental Station, Randwick, for the use of the necessary machines, and to Mr. F. B. Shambler, of the Museum staff, for preparing the test specimens and his assistance during the making of the tests.

EXPLANATION OF PLATES.

Plate VII.—End sections of *Pinus insignis* showing general appearance of wood and rates of growth. Resin canals seen as small dots.

(a) = Gosford;
(b) = Sutton Forest;
(c) = Creswick;
(d) = Mt. Gambier.
(e) = Wirrabara Natural size.

Plate VIII.—*Top*: Wirrabara, transverse section of wood showing narrow zones of late wood; two vertical resin canals seen in section ×37.

Bottom: Wirrabara, transverse section of wood showing narrow late wood zone, false rings, and typical distribution of vertical resin canals ×26.

Plate IX.—*Top*: Sutton Forest, tranverse section of mature wood at junction of early and late wood, showing tendency to form false rings in dense late wood. On right is a horizontal resin canal ×37.

Bottom: Sutton Forest, transverse section of wood near heart showing typical thin walled tissue ×37.

Plate X.—*Top*: Sutton Forest. Longitudinal tangential section of wood showing uniseriate and broader fusiform rays ×37.

Bottom: Sutton Forest. Radial longitudinal section of wood at junction of early and late wood, the variation in size of the tracheids as clearly seen ×37.

Plate XI.—*Right*: Sutton Forest. Longitudinal tangential section of early wood showing uniseriate and fusiform rays and bordered pits in section. ×140.

Left: Sutton Forest. Longitudinal radial section of wood showing distribution of tracheid pits. At the upper edge of the ray the reticulated walls of the ray tracheids are prominent and also the simple pits of the ray parenchyma cells. ×140.

PETROLOGICAL NOTES ON SOME NEW SOUTH WALES ALKALINE BASIC ROCKS.

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(With Plate XII.)

(Read before the Royal Society of New South Wales, Dec. 7, 1927.)

Introduction.

From time to time there have come under the notice of the author examples of alkaline basic rocks from localities not yet recorded. In the absence of intensive field-examination it is generally impossible to write up a detailed account of the occurrences, but as specimens from some half-dozen outcrops in widely-separated localities are now available, some of which were collected several years ago, it has seemed advisable to embody some notes on them in a paper, if only to place the fact of their existence on record, pending, in certain cases, that fuller investigation which is desirable, but which may not be possible for a long time to come.

In no instance is the geological age of the rocks known with certainty—in two cases not even is their actual mode of occurrence in the field definitely known—but there are certain mineralogical characters which permit of a Tertiary age being assigned to all of them with a considerable degree of probability.

The rocks are arranged for descriptive purposes by localities, those specimens which have textural characters in common being grouped together.

Analcite-bearing Basalt, Thirroul.

The officers of the Geological Survey of N.S.W. first drew my attention to the existence of a small sill in the quarry of the Vulcan Refractory Brick Company at Thirroul, on the South Coast, about eight miles north of Wollongong. As a report on the field-occurrence is in preparation, no details need be given here.

The rock composing the sill is aphanitic in hand-specimen, dense and dark-blue, and breaks with rather a splintery fracture. Thin sections show it to be a holocrystalline, fine-grained rock, with intersertal fabric, slightly porphyritic in titanaugite, and with abundant small grains and crystals of olivine, some of which are distinctly larger than the average grain-size of the slide. Fluxional structure is absent. Minerals present: titanaugite, plagioclase, magnetite, olivine, biotite, analcite, and apatite, with a little calcite and serpentine.

The phenocrystic augite prisms are about .6 mm. long, but those of the second generation average not more than .12 mm. The mineral is of a violet-brown colour and pleochroic.

The plagioclase laths are up to about .5 mm. in length and are somewhat zoned. Composition is difficult to determine, but seems to be about that of acid labradorite.

Magnetite and olivine are both fairly abundant, and the rock is therefore probably rather basic. The olivine is changing to a very dark green serpentinous material. Biotite in fairly well-formed tiny flakes is present in quite notable proportion; it shows little or no tendency to form round the iron ore, and for the most part has crystallized quite early.

Analcite is a very subordinate constituent, and is interstitial; it is changing into a brown dusty substance. A few traces of analcitization of the plagioclase are seen. Apatite

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

(H. Gordon Gooch.)

needles are fairly numerous, embedded mainly in felspar and analcite.

This rock is similar to many of the analcite-bearing olivine basalts already described as occurring in dykes about Sydney[1], and in dykes and sills in the Southern Coalfield[2]; it likewise resembles somewhat the basaltic marginal portions of the Prospect intrusion.

Nepheline-basalt, Ulan.

A few years ago the writer paid a flying visit to Ulan, a village near the head of the Goulburn River, about 25 miles north from Mudgee. While there his attention was drawn by Mr. F. Cuningham to an outcrop of basic rock a few acres in extent in the broad valley of the river, about 1½ miles north from Ulan, in portion 52, parish of Ulan. The river-valley, which is here very wide and mature, is cut partly out of granite and partly out of the Permo-Carboniferous and Triassic sediments overlying it. The basalt gives one the impression of being a remnant left from a flow which formerly filled the valley, but has since been almost completely removed by erosion. If this view is correct, since the valley probably dates back to one of the periods of Tertiary peneplanation, the basalt belongs to Tertiary times also.

The rock is holocrystalline, abundantly porphyritic in olivine (up to 1.2 mm.), and sparingly so in augite. The groundmass is composed dominantly of little augite crystals fluxionally arranged, with iron ore and nepheline, felspar being entirely absent. The order of abundance is: augite, olivine, iron ore, nepheline.

The augite, of a pale greenish-brown colour, is in rather elongated prisms averaging about .25 mm. long. Slight pleochroism is observed, but extinction up to 42° has been measured, so that the aegirine-molecule is not prominent; simple and repeated pinacoidal twinning have been noted.

Olivine, with positive birefringence, is altering along cracks to a pale-green, faintly pleochroic serpentine.

Most of the iron ore is magnetite, in little cubes, but ilmenite is also present. The nepheline is entirely interstitial.

But few rocks of this type have been recorded hitherto from New South Wales. Mr. G. W. Card, A.R.S.M., Curator of the Mining Museum, has recorded one such from the Peak, Burragorang[3], and a few from the Western Coalfield[4], in addition to a number of olivine-basalts containing some nepheline. The present rock is, like those mentioned above, along the western margin of the Permo-Carboniferous coal-basin, and though they all probably belong to the much later Tertiary era, their geographical distribution may have some significance. Nepheline-basalt has also been described from the Southern Coalfield.

Analcite-bearing Theralitic Dolerite, Kyogle District.

Through the kindness of Mr. G. W. Card I have been able to examine specimens of an interesting rock from the North Coast District. As regards locality, all that is known at present is that the rock was collected in the Richmond Range, about 20 miles west of the town of Kyogle.

In hand-specimen the rock, which is rather friable, is fine-grained and of a general greyish-brown colour, but mottled and blotched by purplish-black columnar crystals of augite up to 8 mm. long. Occasional clear felspars up to 6 mm. may also be seen, and in the finer-grained portions of the rock, with the aid of a lens, plagioclase and augite can be recognised, with a few small dull-white patches of zeolitic material.

The rock, in thin section, shows many unusual and interesting features. Perhaps the most abundant constituent is plagioclase, in columnar zoned crystals, and apparently

of the composition of labradorite. Some of the crystals have an investment or shell of orthoclase, after the fashion described by Iddings for the absarokites[5]; similar circumgrowth of orthoclase has been observed in some of the monzonitic rocks of Milton, N.S.W.[6]. The slide has been cut from one of the lighter-coloured portions of the rock, consequently the pleochroic pale purple-brown titanaugite is not very abundant; it is partly in columnar, ill-formed crystals, unzoned, but showing traces of hour-glass structure, and partly in skeletal crystals graphically intergrown with nepheline and with plagioclase, somewhat after the fashion described by Benson for the nepheline-dolerites of the Mount Royal Range.[7] Olivine, a subordinate constituent, has an optic axial angle close to 90°, with negative birefringence, and is changing into a dark brown haematitic substance; it is therefore rich in the fayalite molecule. Sometimes it has long, narrow rod-like sections, similar to those occurring in the Bombala rock, described below, and it may be graphically intergrown with plagioclase.

Ilmenite is quite conspicuous, and, in fact, comes next after plagioclase in order of abundance. It is in crystals up to 1.3 mm. diameter, showing a tendency to skeletal habit, and bordered with a narrow fringe of fibrous secondary sphene (?).

A considerable portion of the slide, roughly about 45%, is made up of a kind of matrix or groundmass, in which the minerals just described are embedded. This matrix is rather a tangled maze, consisting mainly of orthoclase, nepheline, soda-pyroxene, analcite, and another zeolite with radiating habit and positive elongation, probably natrolite. Apatite is relatively abundant, in crystals up to 2.5 mm. long, sometimes hollow, and occasionally grouped in parallel fashion.

Orthoclase occurs in small, clear, lath-shaped sanidine-like crystals, with Carlsbad twinning, forming an interlacing network, and in places having a somewhat divergent or sub-radiate disposition, the individuals possessing a distinct curvature.

Nepheline is found as hollow crystals forming a graphic intergrowth with some of the orthoclase investing the plagioclase columns; it likewise occurs graphically intergrown with augite, and forms in part a setting for the little orthoclase laths.

The green, strongly pleochroic soda-pyroxene is wholly interstitial, being moulded on orthoclase laths; its small extinction angle indicates a composition close to aegirine.

Analcite and natrolite, as final crystallizations from the magma, are interstitial to everything else, and in addition have partially replaced nepheline, and eaten into plagioclase peripherally and along cracks. The mutual relations of the two zeolites are by no means clear; analcite seems to have crystallized first, but there is a suspicion that in places a change from analcite to natrolite is taking place.

A remarkable feature of this rock is the prominence of skeletal crystallization and graphic intergrowth, the latter of which may, of course, not necessarily imply simultaneous crystallization, but simply the consolidation of one mineral around the skeleton-crystals of another. Mention has been made above of skeletal and hollow crystals, or of graphic intergrowths, in connection with all the component minerals of the rock.

It is hard to find for this rock a really satisfactory name. It is related to the theralites, the teschenites, and the essexites, while the prominence of orthoclase indicates mineralogical and chemical affinities with the monzonites. Probably the most satisfactory position for it is with the theralites, or their hypabyssal equivalents.

Theralitic Dolerite, Bombala.

About 4½ miles along the road from Bombala towards Cathcart and Candelo the writer, many years ago, collected a specimen of a peculiar-looking basic rock from some road-metal which was being laid, and which evidently came from a neighbouring quarry. It has not been possible since to investigate the occurrence, but Sir Edgeworth David and Dr. Woolnough at a later date discovered the source of the material, and considered it to be an intrusion of some sort. Tertiary basalt has been observed to outcrop in the neighbourhood, and it is pretty evident that this intrusion is of Tertiary age.

The most striking feature of the rock in hand-specimen is the presence of numbers of fresh, dark, columnar augite crystals up to about 5 mm. in length; much of the rest of the rock is rather aphanitic.

In thin section titanaugite and plagioclase are seen to be present in roughly equal proportions. The former is strongly coloured and pleochroic from purplish-pink to light sepia-brown, and is characterised by well-marked hour-glass structure and by a certain amount of colour-zoning, the intensity of the tint deepening towards the periphery of a crystal. The crystals are often hollow, recalling those of the teschenite of the Lugar Sill, described by G. W. Tyrrell[9], and the central cavities, often with rectilinear boundaries, are filled with the material of the matrix or groundmass.

Plagioclase (labradorite about Ab_{35} An_{75}) is in fairly stout to slender columns, exceptionally attaining a length of 7 mm. The felspar dents the pyroxene in places, but both are sensibly idiomorphic, having evidently enjoyed considerable freedom of growth during crystallization.

These large augite and felspar crystals are, as it were, set in a matrix or groundmass forming, roughly, 45%

of the rock, and consisting, so far as can be made out, mainly of pale-coloured titanaugite and nepheline, with olivine, ilmenite, orthoclase, and apatite. The augite is graphically intergrown, in the form of sprays or bundles of divergent elongated slender individuals, with nepheline and with orthoclase. Olivine, which is probably an early crystallization, but has not been found included in the larger augite or felspar, has a very curious habit: some sections up to 6 mm. long are rod-like in appearance, but when examined closely are seen to be in reality composed of rounded or elongated individuals, separate, but set closely together, and in optical continuity, each individual surrounded by greenish decomposition products. These rods may be grouped with a parallel or divergent arrangement. The fact that a few broad skeleton-sections are seen suggests that the olivine has really crystallized in the form of very flat tabular crystals, a somewhat unusual habit. The iron ore, partly magnetite, partly ilmenite, has likewise a tendency to rod-like and skeletal habit, the rods, which are probably compound, attaining a length of 3 mm. Long thin needles of apatite are fairly abundant, often arranged in bundles of four or five individuals in contact, with perfect parallelism.

Orthoclase is not so prominent in this rock as in that from Kyogle, but it has been recognised in little laths, and is probably present in fair proportion. Nepheline, clear and fresh, appears to have crystallized last of all, and acts as host or matrix for the other minerals.

No soda-pyroxene has been detected in this rock, and no zeolite except a very little natrolite (?).

Professor W. N. Benson has drawn attention to the occurrence of intrusions of nepheline- and analcite-bearing dolerites of Tertiary age in various parts of New South Wales and in south-eastern Queensland.[7, 8] The present note

amplifies the record, and adds to the known geographical range of the rocks. Hitherto they had not been found farther south than Sydney; now the proved extent, from Ipswich (Q.) to Bombala, is over 700 miles in a north-south direction.

Analcite-Theralite, near Moonan Flat (Macqueen).

In some notes on the geology and physiography of the Upper Hunter River the writer[10] has made mention of nepheline-bearing dolerites outcropping along the road from Moonan Flat to Barrington Tops. Two occurrences have been noted, one possibly a plug, the other having the appearance of sheets through the Tertiary basalt-flows. The rocks may be called olivine-analcite-theralites provisionally. As these rocks are, with other types from the Barrington Plateau, being made the subject of detailed study by Mr. G. D. Osborne, B.Sc., no further description need be given here.

A Variety of Teschenite-aplite, Prospect.

Much has been writen about the Tertiary alkaline basic intrusion at Prospect, near Parramatta. The most detailed account and discussion of the petrology of the rocks is that given by Jevons, Jensen, Taylor, and Sussmilch.[11]

The intrusive mass is intersected by coarse-grained pegmatitic and fine-grained aplitic segregation-veins, the latter containing but a small proportion of ferro-magnesian constituents, and they usually diopside and aegirine-augite, with a little biotite. Just lately, however, a specimen has been collected by a University student in geology, Miss Lillian Fraser, which is of considerable interest, inasmuch as it contains quite a large proportion of brown barkevikitic hornblende.

Under the microscope the rock is seen to be composed dominantly of felspar-laths, averaging about 1.5 mm. in length, and without any directional arrangement. Some

of these are of basic plagioclase, mostly albitized, and a proportion of the laths is certainly orthoclase, but discrimination is difficult owing to the almost universal kaolinization.

About 15 or 20% of the rock is composed of analcite, isotropic, and mostly perfectly clear and free from turbidity. Tiny apatite-needles are fairly plentiful, and there is a fair sprinkling of little crystals of ilmenite and magnetite. The brown hornblende is present to the extent of about 20% of the rock. In general it occurs as well-formed, well-terminated, slender crystals ranging from 1.8 mm. in length down to about .1 mm. These are scattered fairly uniformly through the slide, embedded indifferently in felspar and analcite.

The mineral shows frequent cross-cracking, and is strongly pleochroic according to the scheme:

X = pale brownish-yellow.
Y = chestnut-brown.
Z = very dark-brown.
$Z > Y > X$

Extinction angles up to 17° were measured in the principal zone; optical character is negative. Pinacoidal twinning was noticed, also interpenetration cruciform twinning. These properties agree well with those of barkevikite, except for the extinction, which is a little high. The distinction between basaltic hornblende and barkevikite by optical means is in general difficult, if not impossible, but in the present instance the association is sufficient to enable one to pronounce pretty definitely in favour of the latter mineral.

A little biotite in well-formed rich brown-coloured crystals is present, and needles of aegirine appear sporadically. The latter is generally in such close association with the hornblende that there is some reason to suspect it of being

a magmatic alteration product, but of this there is no definite proof.

The rock has some affinities, both in mode of occurrence and in component minerals, with the lugarite of Tyrrell,[9] but differs widely from it in the relative proportions of the constituents, and in chemical composition.

Apart from the fact that this is almost the first record of barkevikite for New South Wales, the discovery of this particular variety of aplite serves to bring the Prospect intrusion to some extent into line with the occurrences of hornblende-teschenite.

As a matter of fact, the finding of a suitable name for the Prospect rock has proved somewhat difficult. The mass itself, being of small extent and thickness, may be regarded as a minor intrusion; mineralogically, the rock is fairly uniform in regard to the nature of its essential constitution, and might be classed with either dolerites or gabbros; texturally, if one excludes the aplitic and pegmatitic phases, it varies from basaltic or intergranular to ophitic and subophitic, the absolute grainsize at the same time ranging from fine to coarse-medium. Some of the coarse-grained hypidiomorphic phases of the rock are chemically close to crinanite, while the fine-grained basaltic type approximates to teschenite.

In a short note written in 1924 the present author[12] emphasised the general teschenitic affinities of the rock, but suggested for it the name of olivine-analcite-dolerite rather than teschenite, owing to the absence of barkevikite. That objection, whose validity is at least doubtful, is now to some extent removed, and the name teschenite might well be used for the intrusion as a whole, and in particular for the medium-grained subophitic and hypidiomorphic types, the other textural varieties being termed basaltic and doleritic teschenites respectively.

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EXPLANATION OF PLATE XII.

All photographs are in ordinary light.

Fig. 1.—Nepheline-basalt, Ulan. ×33. Crystals and grains of olivine, augite and iron-ore. The little clear interstitial patches are of nepheline.

Fig. 2.—Theralitic Dolerite, Kyogle District. ×6½. Large crystals of plagioclase, olivine and ilmenite, and groundmass mainly of orthoclase laths and interstitial aegirine. The greyish material on the left side is analcite and natrolite.

Fig. 3.—Theralitic Dolerite, Bombala. ×6½. Note zoned titanaugite, plagioclase, and olivine in divergent dark rods. Groundmass largely of titanaugite intergrown with nepheline and some orthoclase.

Fig. 4.—Teschenite-aplite, Prospect. ×12½. The little dark sections are nearly all barkevikite, the felspar laths show much alteration and the clear interstitial mineral is analcite.

ON SOME METAMORPHOSED DOLERITES FROM BROKEN HILL.

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Assistant-Professor of Geology, University of Sydney.
(With Plate XIII.)

(Read before the Royal Society of New South Wales, Dec. 7, 1927)

Introduction.

In a petrological appendix to the Geological Survey Memoir on the Broken Hill Lode[1] the writer has given a description of the Archaean rocks forming the Willyama Series. The terrain, in the immediate neighbourhood of Broken Hill, consists largely of a series of highly metamorphosed sedimentary rocks, now represented mainly by garnet-sillimanite-cordierite gneisses; these are invaded by primary gneisses of a general granitic character, and by gabbros and gabbro-gneisses, the basic rocks forming sills and sheets which pass through the granite-gneisses in many cases. These latter are also intersected by dykes of aplite and gabbro.

There is ample evidence that the main metamorphism of the sediments was accomplished before the intrusion of the gneisses, but subsequent shearing has resulted in a certain amount of superimposed low-grade dynamic metamorphism, locally intensified. This, however, has to a large extent failed to obliterate pre-existing structures, although in places its effects are visible to a greater or less degree.

It was thought at first that all the basic rocks of the neighbourhood were of later age than the granite-gneisses; since the publication of the Broken Hill Memoir, however, it has become evident that there are basic rocks occurring

quite close to the city, of which some clearly and others possibly represent crystallizations antedating the intrusion of the granite-gneisses. It is with the former division of these that the present paper is concerned.

The rocks in question are all contained within the limits of the outcrop of what is known as the Alma Augen-Gneiss, a coarse porphyritic gneiss forming what Mr. Andrews has called the Mack Plateau, to the east of the township of Alma. This mass is intersected by a number of dykes of gabbroic nature, very comparable in all respects with the gabbro of the sills, intimately associated with aplite in some cases, and clearly intrusive through the gneiss. Some of these basic rocks are coarse, others fine in grain. In certain of the latter the original pyroxene has been wholly or partly altered into green hornblende by shearing, but their affinities with the unaltered gabbros are quite clear.

In addition to these there are a series of small outcrops of fine-grained dark rocks, as well as some dyke-like masses with similar texture, which on the field-evidence and by analogy with the other occurrences were regarded as intrusions. One of these dyke-like masses lies near the eastern end of the Alma rifle-range, runs slightly obliquely to the foliation of the augen-gneiss, and even appears to cut through an aplitic dyke which is clearly satellitic to the gneiss. Microscopic examination of specimens of the basic rock having strongly suggested that it had suffered thermal metamorphism, it was thought that possibly some mistake had been made in labelling the specimens. For this reason no mention of the occurrence was made in the generalised description of the basic rocks given in the Broken Hill Memoir, but when later the opportunity presented itself, further check-specimens were collected and a field-examination of the occurrence was made, by which the previous observations as to the apparent relations of the mass were completely confirmed.

Fig. 1.

Fig. 2.

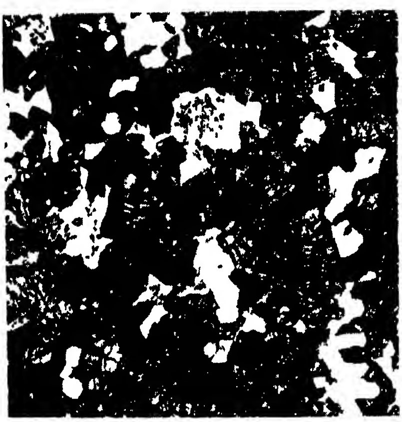

Fig. 3.

Fig. 4

Fig. 5.

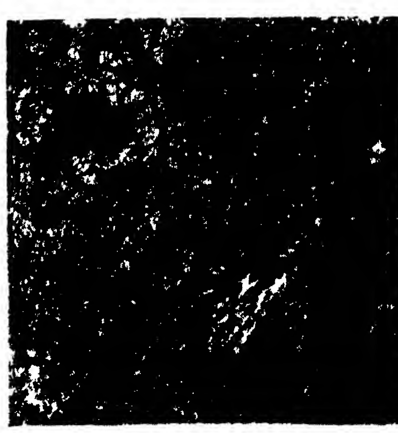

Fig. 6.

(*H. Gordon Gooch.*)

At least four outcrops of rock of this type are represented in the specimens examined.

Petrographical Description.

In hand-specimen the rocks are dark, heavy, compact and massive, without any traces of directional structures. Tiny, dark hornblende grains are conspicuous by reason of their lustre. The different specimens, while having most points in common, show minor variations.

Specimen B120 (Plate XIII, Figs. 1 and 2), from the hill east of the rifle-range, contains plagioclase, augite, brown hornblende, hypersthene and magnetite. Felspar forms about half, and pyroxene and hornblende each about a quarter, of the rock-section, the dark minerals showing clear evidences of a former ophitic relation towards the felspar. The grainsize varies from point to point, this being shown particularly by the columnar felspars, which in some places attain a length of 3 mm., while elsewhere they average about .5 mm. Locally the blastophitic texture is lost through recrystallization, and a granular or granoblastic appearance is produced.

The plagioclase, which is very basic (about $Ab_{26}An_{74}$), is twinned on the albite, Carlsbad and pericline laws: zoning is absent. The habit is mostly sub-columnar, the original outlines having been modified and indented through the recrystallization of the pyroxene. The longer columns are sometimes slightly bent and fractured. A fairly constant characteristic of the felspar crystals is the presence, in their central parts particularly, of tiny inclusions. These are often fairly well-defined crystals, and augite, hypersthene and occasional brown hornblende can be recognised. In suitably-oriented sections strings of little prisms may be seen with their long axes arranged along the pinacoidal cleavage.

Pyroxene is in part primary and in part secondary. The primary augite is in the usual irregular grains or patches up to about 2 mm. in diameter, indented and intersected by felspar prisms. It is light-grey in colour, but was probably darker originally, as the grains are now for the most part heavily schillerized, plates and rods of iron-ore being arranged not merely parallel to (100), but also parallel to the base, and in a direction inclined at about 60° to the vertical axis in sections parallel to (010). Cross-sections show, in addition to the black rods along the diallagic parting, rows of little square dots parallel to (010); these are probably cross-sections of rods. The surface of an augite section is often quite darkened by black magnetite (or ilmenite) dust and rods. The optic axial angle is variable, being sometimes quite low, though no values approaching 0° were observed; the mineral is therefore, in part at least, of the magnesia-rich variety known as enstatite-augite.

Most of the primary augite has been recrystallized into granular aggregates of brown hornblende, augite, and hypersthene, the individual grains averaging about .25 mm. in diameter. The distribution of the hornblende is quite irregular; from some of the replacing aggregates it is quite absent, elsewhere it is the predominating constituent, and sometimes in larger grains it envelopes a felspar, being wholly or partially pseudomorphous after original augite. The pleochroic scheme is: X = yellowish-brown, Y and Z = brown, with extinction in the principal zone up to 20°.

The granular augite is light grey coloured and shows no peculiarities. Hypersthene, though subordinate to the other dark minerals, is present in notable proportion: it is faintly but noticeably pleochroic, and has weak negative birefringence. Where it forms the principal constituent of the granular aggregates, these may represent the recrystallization of a former primary hypersthene.

A little magnetite in tiny granules is included in the secondary hornblende and pyroxene, evidently representing schiller-material not used up by these minerals. The absence of signs of primary magnetite and apatite is noteworthy, likewise the absence of any quartz.

Another specimen, B1320 (Plate XIII, Fig. 3), from the dyke-like mass east of the rifle-range, shows a further stage towards complete reconstitution. The proportion of original pyroxene is smaller than in the first specimen, and while there are many columnar felspars, there is an increase in the proportion of granular felspar. This latter is noticeably free from inclusions, and in many cases shows little or no twinning. Some portions of the thin section have the structure of a typical pyroxene-granulite.

Specimen B1321 (Plate XIII, Fig. 4), from the same mass, shows many of the same characters as those described above. The abundant hornblende is of a greenish-brown colour, and occurs both as a granular mosaic encroaching on the primary augite, and as a replacement to the augite along cracks and cleavage-planes. A feature fairly conspicuous in this slide, but not very prominent in the others, is the occasional inverse zoning of the felspar. As a rule, the small, less basic nucleus is not centrally placed and is irregular or rounded in shape, and it passes outwards by a fairly narrow transition zone into the outer more basic portion. Inverse zoning is a feature noted by Becke[2] and others as characteristic of metamorphic rocks, though it may also be produced under conditions of igneous crystallization.

This specimen has suffered further metamorphism of a regressive nature, which is probably to be ascribed to the period of dynamic metamorphism referred to above. The brown hornblende passes into a colourless type which frays out into a fringe of parallel needles, while the pyroxenes

have been changed partly or wholly into aggregates of brightly-polarising colourless or very pale green needles of amphibole with parallel arrangement. So much of this has straight extinction that one is tempted to regard it as anthophyllite, though much is undoubtedly monoclinic amphibole. Where these aggregates impinge on felspars, they pass over into a narrow border of more distinctly coloured amphibole, pleochroic in yellow-green, green and bluish-green tints.

The amphibole has replaced practically all of the hypersthene; augite has been attacked also, though to a much less extent, while the brown hornblende has suffered least of all. Here and there patches of magnetite-dust testify that the pale amphibole has a smaller iron-content than the mineral it replaces.

The amphibolisation just described is exactly similar to that observed affecting the gabbros of the Broken Hill area in places, and is due apparently to the sensitiveness of pyroxene, and particularly the rhombic variety, to minor crustal stresses.

The rocks above described are all olivine-free, but a number of olivine-bearing types have been collected, some of them from the dyke-like mass at the rifle-range. In B1322 (Plate XIII, Fig. 5), the original ophitic fabric of the rock is clearly recognisable, and the columnar felspars are in places very thickly crowded with tiny inclusions. Traces of original hypersthene are seen, and the segregation or clustering of brown hornblende grains is very marked, these clusters in places enclosing magnetite now coalesced into definite grains.

Olivine probably formed under 5 per cent. of the original rock. It still retains some traces of idiomorphism, but is much cracked, and scored and rimmed with trails of magnetite-dust. Much of the original olivine-substance still

survives, but much has been reconstituted, and is now represented largely by pyroxene. A few traces of a kind of rude centric structure appear, where olivine grains are partially rimmed with pyroxene granules, mostly hypersthene, but nothing in the way of a definite corona-structure exists. The olivine is altering in places to aggregates of colourless amphibole fibres, and elsewhere to ill-defined little patches of talcose (?) material.

The olivine in specimen B141, from a little neck-like mass at the narrowest part of the long southerly projection of the Alma gneiss, just near the municipal tip, is rather more altered. In most cases the site of the mineral is now occupied partly by hornblende and pyroxene granules, but mostly by anthophyllite fibres and hazy talc-like aggregates, and only the strings of magnetite-dust deposited along cracks remain to form a kind of ghost of the original olivine. It is not clear whether these changes are the result of a second metamorphism.

Recrystallization of the pyroxene has not proceeded so far in this specimen as in the others, and the rock has a rather coarser grain. The surface of the augite sections is partially covered with a fine brown dust and with aggregates of tiny brown transparent and translucent brown rods and dots: this discharged material is generally arranged in more or less definite patterns, sometimes approximating to hour-glass shapes.

From the small outcrop just at the southerly tip of the long southerly projection of the gneiss comes a specimen (B147) which shows a number of interesting features (Plate XIII, Fig. 6). Olivine is more abundant, and felspar less abundant, than in the others. The olivine is fairly fresh, but with the usual magnetite along cracks, and this has a marked microdendritic or mossy arrangement. In

the felspar, almost entirely prismatic, the tiny inclusions are so abundant as to impart quite a grey colour to the mineral.

A little hypersthene appears among the primary pyroxene, but by far the greater part of the ferro-magnesian material forms a recrystallized granular mosaic, and at a rough estimate 65 to 70% of this is brown hornblende, while of the pyroxene hypersthene forms a greater proportion than usual.

Another noteworthy feature of this rock, and one found only to a very slight extent in the other olivine-bearing specimens, is the presence of a dark greenish-brown mineral in very tiny granules without definite shape, in some places occurring in little open clusters, but elsewhere aggregated into a solid mass, opaque in the centre, but translucent at the edges, where the dark mineral thins out on top of another transparent one. The properties of this mineral, in so far as they are determinable, agree best with those of the spinel picotite.

Summary of Petrographical Characters.

What appear to be the significant petrographical facts and deductions in regard to the rocks may now be summarised.

The unaltered rocks consisted mainly of columnar basic felspar and pyroxene, including enstatite-augite and hypersthene: magnetite and apatite were scarce or absent. Some of the rocks contained olivine and others were olivine-free. Alteration of the augite has produced heavy schillerization, and then by recrystallization augite, hypersthene and brown hornblende. The last is always plentiful and sometimes predominant: it varies in colour from greenish-brown in some specimens, through golden brown in others, to a reddish-brown, almost like the colour of biotite. It shows

a tendency to form mosaic-aggregates whose individuals are larger than those of the granular pyroxenes and have straight-line boundaries.

The very basic felspar has recrystallized, mostly with the original columnar habit, former impurities or enclosures due to decomposition being now represented by tiny crystals of augite, etc.; in some cases recrystallization has been to clear granular felspar. Inverse zoning has been observed in a number of slides. The felspar content of the rocks is usually fairly high, but declines notably in the rock containing the greatest proportion of olivine. The olivine-bearing rocks contain a small to negligible proportion of what is probably picotite.

The structure of the rocks is blastophitic to granoblastic. Regressive metamorphism is indicated in a few instances, chiefly in the form of amphibolisation, which has affected all the ferro-magnesian minerals, and particularly the hypersthene.

Chemical Changes during Metamorphism.

It is sufficiently evident that the rocks under consideration are metamorphosed dolerites. The original rocks apparently belonged to the quartz-dolerite suite or kindred, which includes olivine-bearing types, and which is characterised by the presence in its members of enstatite-augite, often with rhombic pyroxene, and sometimes with the intergrowth known as pyroxene-perthite, an obscure example of which was detected in one of the slides examined.

The extreme metamorphism of such rocks has been shown to result in the breaking-up of the pyroxenes, with separation of rhombic and monoclinic pyroxenes as distinct grains, the reaction being expressed thus:

$$\left\{\begin{array}{l} mCaMgSi_2O_6 \\ \quad MgAl_2SiO_6 \\ nMgSiO_3 \end{array}\right\} = \left\{\begin{array}{l} mCaMgSi_2O_6 \\ \quad MgAl_2SiO_6 \end{array}\right\} + nMgSiO_3 \quad \ldots\ldots\ldots\ldots (1)$$

A notable feature of some of these rocks is the inverse zoning of some of the plagioclase. This does not appear to have been noted in rocks of similar origin and composition, and it calls for explanation. It really implies that there has been in the process of metamorphism an enrichment of the original felspar in the anorthite molecule, and the lime for this could only be made available by the breaking-down of augite. A reaction such as

$$\left.\begin{array}{l} m\mathrm{CaMgSiO_6} \\ \mathrm{MgAl_2SiO_6} \\ n\mathrm{MgSiO_3} \\ \text{Enstatite-augite} \end{array}\right\} + \mathrm{SiO_2} = \begin{array}{c} (m-1)\mathrm{CaMgSi_2O_6} \\ \text{Diopside} \\ +\,\mathrm{CaAl_2Si_2O_8} \\ \text{Anorthite} \end{array} + \begin{array}{c} (n+1)\mathrm{MgSiO_3} \\ \text{Hypersthene} \end{array} \quad \ldots\ldots\ldots\ldots(2)$$

would provide a means for the production of anorthite in addition to hypersthene and a diposidic pyroxene. For an ordinary aluminous pyroxene a similar reaction would hold, but the resultant hypersthene would be much smaller in amount. The silica necessary for this reaction might be got from the quartz in an original quartz-dolerite, and it may or may not be significant in this connection that, among the rocks studied, inverse zoning of the felspars has been noticed only in the olivine-free types, some or all of which may originally have contained quartz.

Of course, a more basic plagioclase might also be expected to result from the change of augite into hornblende, since in general this involves a release of lime and a taking-up of soda.

The absence of garnet from these rocks is noteworthy. In the various explanations which have been given to account for metamorphic garnet, there has been assumed a reaction between original augite and felspar, with the removal of some anorthite from the latter, or else simply a chemical disintegration of the original augite, involving no interaction with felspar.[3] In the Broken Hill rocks

the absence of garnet may be due to the presence of sufficient free silica to enable reaction (2) to take place, in which case there is a causal relationship between the absence of garnet and the presence of a plagioclase more basic than the original one. But the absence of garnet from the olivine-bearing types shows that some inhibitive factor other than availability of silica must be at work, and this factor may be a physical rather than a chemical one.

Mention has been made of the presence of tiny granules of greenish-brown spinel in certain of the rocks; for this two possible explanations may be suggested. In the first place the spinel may have existed in solid solution in the augite, and during the process of metamorphism may have been forced, like the hypersthene, to take up a separate existence. The spinel should then be expected to appear in any of the rocks, but, as a matter of fact, careful search has failed to reveal it in any but the olivine-bearing types —that is, those in which no quartz could have been present originally. This suggests the second alternative, that there has been desilication of the Tschermak molecule of the original augite, either to provide the silica necessary for the conversion of some of the olivine into hypersthene, or else to enable the reaction expressed by equation (2) to be carried out, thus:

$$\begin{array}{l} m\mathrm{CaMgSi_2O_6} \\ \quad \mathrm{MgAl_2SiO_6} \\ n\mathrm{MgSiO_3} \\ \text{Enstatite-augite} \end{array} \qquad \begin{array}{c} m\mathrm{CaMgSi_2O_6} + n\mathrm{MgSiO_3} + \mathrm{MgAl_2O_4} + \mathrm{SiO_2} \\ \text{Diopside} \qquad\qquad \text{Hypersthene Spinel} \end{array}$$

The time and manner of formation of the brown hornblende are not known with certainty. It may have developed concurrently with the granular augite and hypersthene, but there is a possibility, discussed below, that it belongs to a later period of further partial recrystallization of the rocks under somewhat changed conditions.

Quite a wide range of chemical composition appears to be possible in brown hornblendes: in the present instance the colour probably betokens a special richness in one or other of the iron oxides, and perhaps in titania. These could easily have been supplied by the primary augite, which, if one may judge from its present heavy schillerization, must have been quite highly ferriferous.

The simultaneous recrystallization of hornblende, augite and hypersthene from enstatite-augite may be expressed by the equation:

$$\left\{\begin{array}{l} mCaMgSi_2O_6 \\ \;MgAl_2SiO_6 \\ n\,MgSiO_3 \end{array}\right. \qquad \underset{\text{Diopside}}{CaMgSi_2O_6} + \underset{\text{Hypersthene}}{(n-1)MgSiO_3} + \underset{\text{Hornblende}}{\left\{\begin{array}{l} CaMg_2(SiO_3)_3 \\ MgAl_2SiO_6 \end{array}\right\}}$$

By this reaction, however, the quantity of hornblende produced would be very small in comparison with the pyroxene, which does not accord with what is observed in the rocks. Indeed, there is no constancy in the ratio of hornblende to pyroxene in the recrystallized portions of the rocks, and this and other circumstances, such as the pseudomorphing of original augite by brown hornblende, the occasional marginal conversion of pyroxene into hornblende, and the frequent segregation of hornblende grains into clusters whose individuals are markedly larger than the pyroxene grains, make one feel that the hornblende may really be the product of a subsequent high-grade thermal metamorphism, in the presence of the water or other volatile mineralizers which are necessary for the formation of this mineral.

The inspection of a series of chemical analyses of enstatite-augites reveals the fact that many approach closely some of the hornblendes in composition, owing to the fact that the incorporation of the enstatite molecule lowers the CaO/MgO ratio in the augite to a value comparable with that obtaining in the amphiboles. The change from

pyroxene to brown hornblende would then be little more than a paramorphic one, and this is indeed suggested by the absence of rejected constituents where the hornblende is seen partially replacing original pyroxene.

It is conceivable, too, that some hornblende might arise in a subsequent metamorphism from the recombination of the molecules of the granular augite and hypersthene.

No vestige of biotite has been detected in any of the rocks examined, a rather surprising thing in view of the very common occurrence of biotite and orthoclase in rocks of the quartz-dolerite suite; the absence of secondary sphene, too, is somewhat unusual. It may be that potash and titania were both low in the original rocks, and that they were taken up during metamorphism into plagioclase and pyroxene or amphibole.

Comparison with Analogous Occurrences elsewhere.

Transformations similar to many of those recorded above have been observed in several other areas as the result of high-grade thermal metamorphism of basic igneous rocks.

Sir J. Flett mentions the occurrence of augite in the hornblende-schists of the Lizard,[4] ascribing it either to contact-alteration or to folding and regional metamorphism at high temperatures. The same author, describing the diabase-hornfelses at Land's End,[5] due to alteration by intrusive granites, mentions the very common occurrence, in the extreme stages of alteration, of a pale brown or brownish-green hornblende, with less abundant colourless or pale green augite.

The alteration of diabase round the Dartmoor granite is also of interest in this connection.[6] The first change is the production of much new green or bluish-green hornblende, and this mineral is scattered in enormous quantities in tiny grains through the felspar. Nearer the granite the original

augite is completely replaced by clear brown hornblende quite distinct from the green, iron oxides decrease, and the felspar, originally albite, becomes more basic.

Dr. W. F. Smeeth[7] describes how the Kolar hornblende-schists of Mysore, themselves derived from basic lavas, have been recrystallized into augite-granulites, and in places hornblende-granulites near their contact with an igneous intrusion; and Dr. C. E. Tilley has recorded a somewhat similar case at Carn Chois, Perthshire,[8] where epidiorite-sills and sheets involved in the contact-aureole of a diorite intrusion have been converted into granular augite-hypersthene hornfelses.

Rocks having certain resemblances to those under discussion have been recorded from Adélie Land by Dr. F. L. Stillwell.[9] In these rocks, which are olivine-free, the place of the original columnar felspars has been taken by granular aggregates of secondary felspar, garnet is present, and green, but not brown, hornblende is found. The rocks occur as dykes through garnet-cordierite gneisses, and their characters are attributed apparently to deep-seated regional metamorphism, though the reported occurrence of a pegmatite-dyke in the neighbourhood might suggest the close proximity of a granite-bathylith.

The nearest and most striking analogues to the Broken Hill rocks, both in mode of occurrence and in general characters, are the metadolerites of Southern Eyre Peninsula, described by Dr. C. E. Tilley.[3] The original rocks belonged to the quartz-dolerite group, and some contained olivine. The most noteworthy differences manifested by these when compared with the Broken Hill examples are the presence of garnet and of green instead of brown hornblende, and the greater acidity of, and absence of inverse zoning in, the plagioclase. Tilley interprets the present characters of the rocks as resulting from engulf-

ment of portions of a mass of dolerite in, and their thermal metamorphism by, an acid igneous magna. It is noteworthy that in the occurrences cited by Tilley and Stillwell both hypersthene and augite result from the breaking-up of the original pyroxene.

Origin of the Rocks.

From the evidence of the examples just cited it may be inferred that augite and hornblende may be produced as the result of high-grade thermal alteration of basic rocks. Augite may apparently result from regional and contact-metamorphism, and brown hornblende from contact-metamorphism, but in this connexion it is to be noted that Grubenmann[10] has considered the probability that the brown hornblende found in the altered basic rocks of his "kata-zone" has formed under the same deep-seated conditions as the augite, in contrast with the green hornblende which is characteristic of the "meso-zone".

From the internal evidence of texture it may be inferred that the Broken Hill rocks crystallized originally as intrusives, though not necessarily in their present surroundings; the grainsize and the ophitic fabric indicate clearly hypabyssal conditions of consolidation. The alteration shows that they have subsequently suffered a high degree of thermal metamorphism. There remain, then, to be discussed the time of intrusion and the time and circumstances of the metamorphism. The sedimentary rocks among which the augen granite-gneiss is injected had, previously to its intrusion, been converted into garnet-sillimanite-cordierite gneisses with "kata-zone" characters and a fairly pronounced schistosity. At a later date, and during the continuance of the folding, the granite-gneiss was injected, and had impressed on it during crystallization a primary gneissic foliation. Subsequent local shearing superinduced a further low-grade metamorphism

which, however, did not obliterate, though it modified, the primary gneissic structure.

However, the point to be emphasised is that there is no evidence of high-grade metamorphism having affected the granite-gneiss subsequently to its cooling, and the masses of altered dolerite within its borders must therefore, in spite of the dyke-like appearance of some of them, be interpreted as inclusions of pre-existing rock-masses, engulfed in the gneiss magna at the time of its injection. This being so, there are two possible alternatives as to the time of formation of the dolerites:

(1) they were injected after the metamorphism of the sedimentary series and immediately before the injection of the augen-gneiss; or

(2) they were injected into the sediments before the metamorphism of the latter.

Under the first assumption the present condition of the rocks is entirely due to contact-metamorphism and engulfment in the granite-magna. As opposed to this first view and more in harmony with the second is the ophitic fabric of the original rocks. The granular and gabbroic textures are usually regarded as belonging to large deep-seated basic intrusions, and the ophitic as being characteristic rather of smaller hypabyssal injections and of surface-flows. It is therefore more natural to associate ophitic dolerites with dykes or sills through a series of unaltered sediments than to imagine them as heralding deep-seated granite-gneiss injections through a terrain still undergoing metamorphism under conditions of mountain-building and deep burial. It seems preferable, then, to ascribe these rocks to a period antedating the metamorphism of the sedimentary rocks. This implies that they received their first and probably their main metamorphic impress under regional conditions. Whether brown hornblende as well as pyroxene was formed

then it is impossible to say. But the hornblende is very variable in its proportions and very uneven in its distribution through the rocks within the limits of a single occurrence, and we know that this mineral requires the existence of "wet" rather than "dry" metamorphic conditions, and has been recorded as a contact-mineral; perhaps, therefore, it is most reasonable to ascribe the secondary pyroxene to the first or regional metamorphism, and the brown hornblende to the subsequent high-temperature, "wet" alteration of both primary and recrystallized pyroxene during and as a result of engulfment in the granite-gneiss magma.

Summary.

Petrographical descriptions are given of a series of basic rocks enclosed within the outcrop of a granitic augen-gneiss at Broken Hill. These have been originally ophitic dolerites belonging to the quartz-dolerite kindred, and have suffered high-grade thermal metamorphism, with the production of augite, hypersthene, brown hornblende, very basic plagioclase, and in some cases a little spinel, with partial or complete obliteration of original textures.

An attempt is made to indicate the general nature of the probable chemical reactions taking place during metamorphism, and the time and manner of alteration are discussed. It is considered most probable that the rocks first suffered extreme regional metamorphism and subsequently underwent contact-metamorphism with engulfment at the time of the injection of the granite-gneiss.

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EXPLANATION OF PLATE XIII.

Fig. 1.—Slide B120. Ordinary light. × 33. Note hornblende (dark grey), primary augite with schiller-inclusions, and plagioclase. Traces of ophitic fabric still visible.

Fig. 2.—Same as Fig. 1. Crossed nicols. Shows modified columnar habit of plagioclase.

Fig. 3.—Slide B1320. Ordinary light. × $17\frac{2}{3}$. Recrystallization has produced an approach to granoblastic structure.

Fig. 4—Slide B1321. Crossed nicols. × 45. In the centre is a grain of plagioclase with inverse zoning, the more basic shell being at extinction: the grain also shows traces of albite and pericline twinning. Above and to the right are relatively large grains of brown hornblende.

Fig. 5.—Slide B1322. Ordinary light. × $17\frac{2}{3}$. Ophitic fabric is plainly evident. Note cluster of hornblende grains at right top, granular pyroxene elsewhere, and felspars crowded with tiny inclusions.

Fig. 6.—Slide B147. Ordinary light. × $17\frac{2}{3}$. Note olivine grains at top left and bottom right, between them a little felspar with hornblende inclusions, and at top left a cluster of spinel. Rest of field consists mostly of little hornblende and pyroxene grains.

DESCRIPTIONS OF FOUR NEW SPECIES OF BORONIA,

WITH NOTES ON CERTAIN OTHER SPECIES.

By Edwin Cheel,

Curator of the National Herbarium, Sydney.

(Read before the Royal Society of New South Wales, Dec. 7, 1927.)

In working over the large collection of specimens of the genus *Boronia* contained in the National Herbarium one cannot but notice the extreme variation of the material representing the various species. In a previous paper published in the Journal and Proceedings of this Society (11) I endeavoured to show that at least two species were worthy of separate entity from the pinnate-leaved series and in continuation of my investigations I now submit descriptions of four species which do not appear to have been previously described, together with notes on certain other species which have been incorporated as synonyms, and composite descriptions drawn up to cover the supposed variations.

The following is a synopsis of the species dealt with in the present paper:—

B. subulifolia sp. nov. Previously included under *B. pilosa*, but the latter and its forms are confined to Tasmania and South Australia.

B. hispida sp. nov. Previously included under *B. polygalifolia* as a variety.

B. Ruppii sp. nov. Somewhat related to *B. Fraseri.*

B. Whitei sp. nov. Affinities with *B. granitica.*

B. oppositifolia. This was misdetermined as a *Tetratheca* by Persoon. De Candolle restored it to the genus Boronia as *B. tetrathecoides,* quoting Persoon's name as a synonym. Persoon's specific name, being the older, has priority over De Candolle's name. It has distinctive characters from those of *B. polygalifolia* and is quite common in Tasmania and is also found in South Australia, Victoria and inland districts of New South Wales.

B. ledifolia is discussed in conjunction with *B. rosmarinifolia, B. triphylla, B. repandra and B. rubiginosa,* which are regarded as specifically distinct and are accordingly raised to specific rank. The var. *glabra* is also raised to specific rank.

Boronia subulifolia, sp. nov.

Fruticulus ramosus, ramulis et foliis plus minus ve dense hispidis; foliis breviter petiolatis, pinnatis, 7-9 subteretis vel subulatis segmentis; floribus axillaribus solitariis brevissime pedunculatis; sepalis ad basim latis, ad apicem subulatis; petalis rufis.

Plant 1 to 1½ feet high and fairly widespread in habit, the branches and leaves rather densely hispid. Leaves crowded, on a very short petiole, with 7 to 9 leaflets or rarely less than 7, the leaflets sub-terete or subulate with a slight channel along the upper surface; about 5 to 7 lines long. Flowers singly in the axils of the leaves, on very short pedicels. Sepals about 2 lines long, broad at the base, but gradually tapering into subulate points, and more or less hispid. Petals reddish colour, about 4 or 5 lines long. Fruits and seeds not seen.

This has previously been included with *B. pilosa,* but is distinct from that species in the flowers being larger and singly in the axils of the leaves, on short pedicels not more than a line long, whereas those of *B. pilosa* are

usually in terminal or axillary cymes. Some forms of *B. pilosa* from the Grampians in Victoria seem to be nearer this species than the typical *B. pilosa* or the varieties *floribunda* and *laricifolia* of Tasmania. The pedicels of the flowers of *B. pilosa* and its varieties are much longer than those of *B. subulifolia.*

The late Mr. Maiden stated in a footnote (Proc. Linn. Soc., N.S.W., 1889, p. 108) that it was "probably brought to the Clyde Mountain from Tasmania". Specimens in the National Herbarium, Sydney, are from Braidwood district, 3800 feet alt., collected by Mr. W. Bauerlen, and Currockbilly Mountain, near Braidwood (J. L. Boorman).

Boronia hispida, sp. nov.

(*B. polygalifolia* var. (?) *pubescens* Benth. Fl. Aust. I, 321, 1863).

Fruticulus omnibus partibus hispidis; foliis trifoliatis; segmentis ternatis, ovatis vel obovatis, ad 4 mm. longis; floribus axillaribus solitariis; sepalis acutis, 2 mm. longis; petalis albidis vel pallidi-puniceis, externe hispidus; filamentis ciliatis; antheris minute apiculatis; stylo piloso.

Plants with a stocky root-growth, varying in height from six to about fifteen inches. The whole plant hispid. Leaves trifoliate, the leaflets ternately arranged on a petiole about 2-3 mm. long; leaflets small, ovate to obovate in general outline, rarely exceeding 4 mm. in length, hispid on both sides. Flowers solitary in the axils of the leaves, the pedicels slightly exceeding the petioles. Sepals acute, hispid, about 2 mm. long. Petals white or pale-pink, hispid on the outside, about half as long again as the sepals. Stamens slightly shorter than the petals, the filaments ciliate and anthers terminated by a minute apiculae. Style pilose.

This species was originally recorded for the Grampians in Victoria by Bentham (8) under *B. polygalifolia* as var.

(?) *pubescens.* It is quite distinct from any of the forms of *B. polygalifolia,* and is worthy of specific rank. Its nearest ally is *B. robusta,* but it can easily be separated by the hispid sepals and petals, which are quite glabrous in *B. robusta.* It also resembles *B. nana,* but may be separated from that species in the hispid nature of the floral organs.

Habitat: Victoria, without specific locality, ex Herb Hooker; Grampians, C. Walter, November, 1900; Victorian Ranges, H. B. Williamson, November, 1903; New South Wales, Head of the Turos River, R. H. Cambage (No. 1983), November, 1908.

Boronia Ruppii, sp. nov.

Fruticulus 30-90 cm. altus; foliis trifoliatis, nonnunquam simplicibus; breviter petiolatis, crassiusculis, glabris, ovatis; floribus axillaribus umbellatis, pallidi-puniceis; sepalis ovato-lanceolatis acutis; petalis valvatis; staminibus ad basim aliquantum conjunctis, filamentis ciliatis, plus minus ve glandulosis; antheribus apiculatis; seminibus magnis, rugosis, opacis.

Plants usually about 12 to 18 inches high, or occasionally up to 3 feet. Leaves trifoliate, or sometimes reduced to simple leaves; leaflets 1-2 cm. long by 1 cm. broad, on short petioles, ovate, glabrous, rather thick, and concolourous of a paler green than in *B. ledifolia.* Flowers axillary, in small umbels, light coral-pink. Sepals ovate-lanceolate, rather acute, 5 mm. long. Petals valvate, rather more than twice as long as the sepals. Stamens slightly cohering at the base into a ring; filaments ciliate and more or less glandular, especially the four longest, the anthers with an appendate. Style small, stigma somewhat grooved. Seeds large, rugose, opaque.

This species seems to be restricted to the Woods' Reef Serpentine, and was originally collected by the Rev. H. M. R. Rupp at Wollombin in September, 1912, and afterwards by Mr. A. J. Spencer.

It is named in honour of Rev. Herman Montague Rucker Rupp, who has devoted a good deal of attention to the study of Australian plants.

The affinities of this species are with *Boronia Fraseri*, but the leaves are not pinnate as in that species, and it also somewhat resembles *B. rubiginosa*, but the leaves of the latter are also pinnate and densely covered on the under surface with stellate hairs.

Boronia Whitei, sp. nov.

Fruticulus erectus ramosus; caulibus plus minus ve hirto stellato ornatis; foliis pinnatis, 5-9 segmentis, supra glabris subtus stellato-tomentosis; floribus axillaribus solitariis, nonnunquam 2-3; petalis rufis, stellato tomento ornatis; filamentis ciliatis; antheris ovatis vel cordatis, erectis.

Plants about two feet high, erect, shrubby habit, the stems more or less covered with stellate hairs. Leaves pinnate, 5-9 leaflets, the rachis slightly winged, covered with a dense nappy growth; leaflets smooth and shiny on the upper side, the margins revolute and the underside of the leaflets covered with a nappy growth of stellate hairs. Flowers solitary in the axils of the leaves, or occasionally in clusters of 2 to 3 flowers, on pedicels 1 or 1½ cm. long. Sepals comparatively broad, about 2-4 mm. long; petals rosy-red colour, covered on the outside with a nappy growth of stellate hairs, similar to that on the underside of the leaves and sepals. Filaments ciliate; anthers ovate or heart-shaped, erect, without any appendate. Style linear, or nearly so.

This plant somewhat resembles *B. alulata* in foliage, but the sepals are longer and almost subulate and the leaflets more numerous than in *B. alulata*. It also somewhat resembles *B. granitica*, but the branches and branchlets, calyx-lobes and petals of the latter are more woolly-white, and the central nerve of the petals of *B. granitica* is lined with stellate hairs.

This was originally collected at Tent Hill, New England, by Mr. E. C. Andrews in 1903, and determined by the late Mr. J. H. Camfield as *B. ledifolia* var. *denticulata*, to which a note is appended by the late Mr. E. Betche—"I see no denticulations on the leaves. It seems to me the ordinary pinnate-leaved form". There are also specimens from Emmaville (J. L. Boorman, June, 1904); Torrington (R. H. Cambage, Nos. 1609 and 1715, July and September, 1907), with a note by the late Mr. E. Betche:—"Probably an unnamed variety", also from Torrington collected by J. L. Boorman in November, labelled *B. ledifolia* var. *rubiginosa* and afterwards *B. ledifolia* var. *pinnata*. Then we have specimens from Bismuth, via Torrington, collected by Mr. A. McNutt in August, 1912 and 1924, the former collection labelled *B. ledifolia* var. *triphylla*. It is quite distinct from *B. denticulata*, *B. rubiginosa* and *B. triphylla*.

I have named this species in honour of John White, Surgeon-General to the Settlement in Port Jackson, who landed in 1788 and made the first collection of specimens on which the genus *Boronia* was founded by Sir James Edward Smith.

Boronia polygalifolia Sm.

The original plants upon which Smith (38) founded this species were collected in the Port Jackson district by John White, Esq., Surgeon-General to the Settlement in 1788. De Candolle (15) and Don (15a) seem to have regarded the Port Jackson plants as distinct from the Victorian and Tasmanian forms and these were accordingly described under the name *B. tetrathecoides*. It appears that Persoon (35) had mistaken it for a species of *Tetratheca* and included it under that genus as *T. oppositifolia*, but De Candolle recognised it as a species of *Boronia* and accordingly transferred it to that genus as a synonym.

Sprengel (39) considered Sieber's *B. hyssopifolia* identical with Smith's *B. polygalifolia.* Mueller (34) drew up a composite description and included the following species as synonyms—*B. bipinnata* Lindl. (24), *B. anemonifolia A.* Cunn. (13), *B. nana* Hook. (19), *B. dentigera* F.v.M. (33), and *B. tetrathecoides* DC. (15). Bentham (8), however, regarded *B. nana* of Hooker as a variety and unites it with *B. polygalifolia* as *var. trifoliolata,* probably taking his cue from Hooker (18), who for some reason or other sank his *B. nana* under *B. hyssopifolia* Sieb., with the following remarks:—"So closely resembling the last (B. pilonema) as to require no detailed description. The seeds are very large, oblong, and covered with a granulated opaque testa, glistening with minute copper-coloured points when dry. I cannot distinguish this from the preceding without the seeds, for the hairs on the filaments afford a very inconstant character. Dr. Mueller has sent from South-eastern Australia what appears to be this species (under the name of *B. tetrathecoides*), with the leaves simple below, and trifoliolate above; whilst a few intermediate ones are lobed at the apex. As it is not in fruit I cannot identify it with the Tasmanian plant, or I should adopt the name *B. tetrathecoides,* for the present. Also Dr. Mueller sends the ordinary state of the plant, under the name of *B. tetrathecoides var. simplicifolia;* and another with broad leaflets, and densely pubescent leaves and branches, as *var. pubescens;* no two species can well be more dissimilar than these varieties are, and I have no reason to doubt Dr. Mueller's correctness; it only shows how much more good is to be done by studying the variations of the plants, rather than by describing different forms as new species. My *var. β** again only differs in having most of the leaves trifoliolate, a few of the lower being simple. I have not

* This is *B. nana* Hooker (19).

seen the seeds of it, but Gunn says of them, that they differ from those of all the other species but *B. hyssopifolia*, which he rightly describes as opaque."

In the National Herbarium, Sydney, there is a specimen from Timbarra, upper Murray River, collected by C. Stuart ex Phytologic Museum, Melbourne, labelled "*B. hyssopifolia var. simplicifolia*", in Luehmanns' handwriting. The late Mr. Betche remarked, "*var. simplicifolia* seems to be Luehmanns' name unpublished." It is evident that Mr. Betche had not seen Hooker's remarks cited above, and that he also concluded that *B. tetrathecoides* DC., *B. hyssopifolia* Sieb., and the *var. simplicifolia* F.v.M., were synonyms of *B. polygalifolia* Sm. My own view is that *B. tetrathecoides* of Mueller and De Candolle (15) is sufficiently distinct from *B. polygalifolia* Sm., to be re-habilitated to specific rank again.

Boronia oppositifolia (Pers.) comb. nov.

This species was originally described by Persoon (35) as *Tetratheca oppositifolia*. The description is in Latin and may be translated as follows:—"Leaves somewhat sparse linear-lanceolate, opposite, flowers erect." In a foot note Persoon also makes the following remarks:—"These two species (*Tetratheca oppositifolia* and *T. ericæfolia**) I have examined in the collection of Australian plants made by Thibaud (in Nee's collection)." Then we have *Boronia tetrathecoides* of De Candolle (15), which is described in Latin and translated in English by Don (15a) as follows:—"Leaves linear, quite entire, smooth, rather acute at both ends, and somewhat revolute on the edges; peduncles axillary, I-flowered, short, each bearing 2 bracteas; filaments hispid. Native of New Holland, on the eastern coast. *Tetratheca oppositifolia* Pers. ench. I., p. 419. Flowers rose-coloured. Tetratheca-like Boronia."

* *T. ericæfolia* is a true *Tetratheca*.

Although the name *Tetratheca oppositifolia* of Persoon is quoted as a synonym of *B. tetrathecoides* by both De Candolle and Don, no reference is made to this name by Bentham, Mueller or other workers on Australian plants. Hooker (21) also quotes *B. tetrathecoides* as a Tasmanian plant, but attributes the species to Persoon instead of to De Candolle, and includes *B. hyssopifolia* of Sieber as a synonym with the following remarks:—"This is very near *B. pilonema* of Labillardiere, but in that the flower is always terminal (here constantly lateral), and the filaments are naked." In a subsequent work, Hooker (18) takes up the name *B. hyssopifolia* Sieb. and includes the name *B. tetrathecoides* as a synonym. Although there is a superficial resemblance between the plants of *B. polygalifolia* of Sm. (38), which are common in the Port Jackson district, and those of *B. oppositifolia* (Pers.) (Syn. *B. tetrathecoides* D.C.), originally collected by Mueller on the Buffalo Ranges in Victoria, the latter can easily be separated by an examination of the branches and branchlets which are hispid, whereas those of *B. polygalifolia* are perfectly smooth and glabrous. The latter seem also to be confined to the coastal districts of New South Wales and Queensland, whereas *B. oppositifolia* ranges from the Blue Mountains and inland districts of New South Wales to the Buffalo Ranges in Victoria, and also extends to Mount Lofty and Onkaparinga in South Australia. It is also quite common in Tasmania. The following is a list of specific localities as represented in the National Herbarium, Sydney:—

N.S.W.—Kanimbla Valley (J. J. Fletcher), Mount Victoria (E. Cheel), Queanbeyan (R. H. Cambage, No. 3304), Germanton tó Tumberumba (W. Forsyth), Rosewood via Wagga (—. McEachern), Tooma, Upper Murray River (J. L. Boorman).

Victoria.—Buffalo Ranges (S. G. Hannaford), and without specific locality (A. H. S. Lucas).

Tasmania.—Sandhill, in sandy soil in a field on the Hobart Town Road near Launceston (R. C. Gunn, No. 458), W. H. Archer, without specific locality.

Although I have not seen the original specimens described by Persoon, I have taken up the name "*oppositifolia*" as it has nineteen years' priority over *tetrathecoides*, and as De Candolle includes it as a synonym we may safely assume that the two names cover the one species.

Boronia ledifolia J. Gay.—The original plants of this species were collected in the Port Jackson district and described by the French Botanist, Etiene Pierre Ventenst (40), under the name *Lasiopetalum ledifolium.* It was afterwards transferred to the genus *Boronia,* and when the typical forms are compared with certain plants of the genus *Ledum* (Fam. Ericaceae), we can quite understand the origin of the specific name. It has a fairly wide range, as specimens are represented in the National Herbarium from the Port Jackson district, and also from Copmanhurst on the Clarence River. Much confusion has been caused through the mixing up of this and the following species and sub-species and varieties, and several writers seem to infer that there are great difficulties in distinguishing the trifoliate-and-pinnate-leaved forms from the typical *B. ledifolium.* Smith (37), for example, included it in the genus *Eriostemon* as *E. paradoxa* (Various-leaved Eriostemon), and at the conclusion of a composite description remarked: "In one variety they (the leaves) are simple, almost perfectly opposite; on short foot-stalks; in another, small ternately sessile on one common winged stalk." Bentham (8) recognised three varieties, and Maiden and Betche have to a certain extent followed him with the following remarks:—"The pinnate-leaved forms of *B. ledifolia* are

always variable, the 3-foliate form of leaves merging into the pinnate forms (30)." On the other hand, Don (15a) remarked: "It is doubtful whether the simple, ternate, and pinnate leaves are to be found on the same plant; we presume they belong to distinct species, and are probably identical with some of those described above." After a considerable amount of study, both in the field as well as with herbarium material, I find that the species set up by A. Cunningham and Sieber have very distinct characters, and I propose to re-habilitate them to specific rank again and have accordingly drawn up a descriptive key to define their distinctive characters.

Boronia repanda Maiden & Betche (31).—This was originally regarded as a var. of *B. ledifolia* by Mueller and Maiden & Betche, but was raised to specific rank by the latter authors (31), who record it from Maryland and Stanthorpe. *B. ledifolia* var. *denticulata* Moore & Betche (32), implied from Mueller (34a), who remarks: "A var. (*ledifolia*) with somewhat denticulated leaflets.—Cobar, H. Andrae." There are no specimens of this in the herbarium so that I am unable to express any definite opinion, but it seems to me to come very near *B. repanda*, and may not be specifically distinct from that species.

Boronia glabra Maiden & Betche.—(*B. ledifolia* var. *glabra* Maiden & Betche (27)). The original specimens were collected on the Harvey Ranges near Peak Hill. It has since been recorded from Baraqula and Canal Creek, Queensland, by White & Francis (41). The leaf characters alone are sufficient to separate this from any of the other species.

Boronia rosmarinifolia A. Cunn. (14). (*B. ledifolia* var. *rosmarinifolia* Benth).—The original specimens were collected on Peel's Island, Moreton Bay, by A. Cunningham in 1824. It has since been collected from the following localities, and seems to me to be quite distinct from any

of the other species:—Port Jackson District, Grafton, and Copmanhurst in New South Wales; Brisbane, Sunnybank, Beaudesert and Stradbrooke Island in Queensland.

B. rosmarinifolia var. *albiflora.*—Similar to the normal form, but the flowers pure white instead of rose-pink. See (12) for record.

Boronia triphylla Sieb (36). (*B. ledifolia* var. *triphylla* Benth. (8).—The original specimens were collected in the Port Jackson district, and it seems to be the most common species, being found on sandstone country as far as Mittagong on the southern tablelands as well as being quite common on the Blue Mountains. The specimens recorded by Mueller (34a) from the Culgoa River may probably belong to this species. The species mentioned in "The Garden," September 23 (1876), 312, is probably this and not "ledifolia".

B. triphylla var. *flore-plena.*—Similar to the normal form but the flowers are double. See (12) for original record.

Boronia rubiginosa A. Cunn. (14). (*B. ledifolia* var. *rubiginosa* Benth.) *B. ledifolia* Maiden & Betche (28).—The original specimens were collected on the Hunter River by A. Cunningham in 1827. The leaf-characters are distinctive in that the leaflets are broad (not revolute as in the other species), and vary from 3 to 5 or occasionally 7 leaflets, and the flowers are sometimes solitary, sometimes in more or less ramified or bifarious cymes or occasionally umbellate. The plant figured in Bot. Reg. t. 47 and Paxt. Bot. Mag. VIII. 125, seems to be a form of this species rather than *B. triphylla*.

Specimens in the National Herbarium which may be referred to this species are from the following localities:—

Cowan Creek, Berowra, Hawkesbury River (opposite Milson Island), Denman, Mount Dangar and Gungal near Merriwa, Coff's Harbour to Grafton, and Coramba Mountains on the Orara River.

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ABSTRACT OF PROCEEDINGS

ABSTRACT OF PROCEEDINGS

OF THE

Royal Society of New South Wales.

MAY 4, 1927.

The Annual Meeting, being the four hundred and sixty-eighth General Monthly Meeting of the Society, was held at the Society's House, 5 Elizabeth Street, Sydney, at 8 p.m.

Dr. W. G. Woolnough, President, in the chair.

Forty-three members were present.

The Minutes of the General Monthly Meeting of the 1st December, 1926, were read and confirmed.

The President announced the deaths of the following members:—Dr. Thomas Fiaschi, elected in 1881; Mr. F. B. Guthrie, elected in 1891; and Mr. W. J. Newbigin, elected in 1926.

A letter was read from Mrs. F. B. Guthrie, expressing thanks for the Society's sympathy in her recent bereavement.

The certificates of six candidates for admission as ordinary members were read for the first time.

The Annual Financial Statement for the year ended 31st March, 1927, was submitted to members, and, on the motion of Professor H. G. Chapman, seconded by Dr. H. S. H. Wardlaw, was unanimously adopted.

GENERAL ACCOUNT.

RECEIPTS.

	£ s. d.	£ s. d.	£ s. d.
To Revenue—			
Subscriptions		694 1 0	
Rents—			
Offices	636 7 0		
Hall and Library ..	287 17 8		
		924 4 8	
Sundry Receipts		19 0 11	
Government Subsidy for 1926		400 0 0	
			2037 6 7
,, Clarke Memorial Fund—			
Loan to General Fund (interest)			67 19 8
,, Building Investment Fund—			
Loan to General Fund ...			300 0 0
,, H. G. Smith Memorial Fund ...			101 16 6
,, J. H. Maiden Memorial Fund ..			266 18 0
,, Balance--31st March, 1927.			
Union Bank of Australia Ltd.			
Overdrawn Account, Head Office		983 10 9	
Less Petty Cash on Hand ...		2 14 10	
			980 15 11
			£3754 16 8

PAYMENTS.

	£ s. d.	£ s. d	£ s. d.
By Balance—31st March, 1926 ...			1259 9 7
,, Administrative Expenditure—			
Salaries and Wages—			
Office Salary and Accountancy Fees	279 15 0		
Assistant Librarian	48 0 0		
Caretaker	252 0 0		
		579 15 0	
Printing, Stationery, Advertising and Stamps—			
Stamps and Telegrams ..	40 18 10		
Office Sundries, Stationery, &c.	7 16 1		
Advertising	10 1 0		
Printing	53 6 0		
		112 1 11	

Rates, Taxes and Services—			
Electric Light	55 4 10		
Gas	9 10 5		
Insurance	41 8 11		
Rates	210 18 2		
Telephone	13 12 11		
		330 15 3	
Printing and Publishing Society's Volume—			
Printing, &c.	213 11 6		
Bookbinding	46 13 9		
		260 5 3	
Library—			
Books and Periodicals ...	47 15 6		
Bookbinding	46 14 9		
		94 10 3	
Sundry Expenses—			
Repairs	8 9 10		
Lantern Operator	21 11 9		
Bank Charges	0 10 6		
Sundries	50 14 9		
		81 6 10	
			1458 14 6
,, Interest—			
Union Bank of Australia Ltd.		93 9 9	
Clarke Memorial Fund ...		67 19 8	
Building Loan Fund		64 3 9	
H. G. Smith Memorial Fund		11 4 6	
			236 17 8
,, Building and Investment Fund ...			300 0 0
,, H. G. Smith Memorial Fund ..		215 0 0	
,, H. G. Smith Memorial Fund Administration		5 6 0	
			220 6 0
,, Building Loan Fund			279 8 11
			£3754 16 8

CLARKE MEMORIAL FUND,

BALANCE SHEET AS AT 31st MARCH, 1927.

Liabilities

	£ s. d.	£ s. d.
Accumulation Fund—		
Balance as at 31st March, 1926	1029 3 7	
Additions during the year—		
Interest and General Fund	67 19 8	
		1097 3 3
		£1097 3 3

ASSETS.

	£	s.	d.
Loan to General Fund	1097	3	3
	£1097	3	3

STATEMENT OF RECEIPTS AND PAYMENTS FOR THE YEAR ENDED 31ST MARCH, 1927.

RECEIPTS.

	£	s	d.
To Interest—Loan to General Fund	67	19	8
	£67	19	8

PAYMENTS.

	£	s.	d.
By Loan to General Fund...	67	19	8
	£67	19	8

BUILDING AND INVESTMENT FUND. BALANCE SHEET AS AT 31ST MARCH, 1927.

LIABILITIES.

	£	s.	d.	£	s.	d.
Accumulation Account—						
Balance as at 31st March, 1926	700	0	0			
Additions during the year—	300	0	0			
				1000	0	0
				£1000	0	0

ASSETS.

	£	s.	d.
Loan to General Fund	1000	0	0
	£1000	0	0

Compiled from the Books and Accounts of the Royal Society of New South Wales, and certified to be in accordance therewith.

(Sgd.) HENRY G. CHAPMAN, M.D.,
Honorary Treasurer.

(Sgd.) W. PERCIVAL MINELL, F.C.P.A.,
Auditor.

SYDNEY, 21ST APRIL, 1927.

On the motion of Mr. G. Hooper, seconded by Mr. A. E. Stephen, Mr. W. P. Minell was duly elected Auditor for the current year.

The Annual Report of the Council was read, and, on the motion of Mr. R. H. Cambage, seconded by Mr. E. Cheel, was adopted.

Annual Report of the Council for the Year 1926-1927.

(1st May to 27th April.)

The Council regrets to report the loss by death of nine ordinary members. Twelve members have resigned. On the other hand, eleven ordinary members have been elected during the year. To-day (27th April, 1927) the roll of members stands at 360.

During the Society's year there have been eight general monthly meetings and nine Council meetings.

The Building Committee has held several meetings during the year, with representatives of the Linnean Society of N.S. Wales and the Institution of Engineers (Australia), to discuss the question of building a Science House, in which all the various scientific institutions can be accommodated, but no complete scheme has yet been formulated.

Four Popular Science Lectures were given, namely:—

June 17—"Sound Waves," by Mr. E. T. Fisk.

July 15—"Drifting Continents," by Prof. L. A. Cotton, M.A., D.Sc.

August 19—"The Sydney Harbour Bridge," by J. J. C. Bradfield, D.Sc.Eng., M.E., M.Inst.C.E.

September 16—"Some Chemical Wonders of Australia Native Plant Life," by A. R. Penfold, F.A.C.I., F.C.S.

On April 4th, 1927, a lecture was given by Mr. E. Jerman, Director of Education, Victor X-Ray Corporation, Chicago, entitled, "The Modern Application of the X-Rays to Science and Industry."

Meetings were held throughout the Session by the Sections of Geology, Agriculture, and Physical Science.

The Section of Industry, during the year, instead of holding evening meetings, devoted its attention to visiting several of the many industrial establishments.

Twenty-seven papers were read at the monthly meetings, and covered a wide range of subjects. In most cases, they were illustrated by exhibits of interest.

The Annual Dinner took place at the Union Refectory, Sydney University, on Thursday, 29th April, 1926, when we were honoured by the presence of His Excellency Sir Dudley Rawson Stratford de Chair, K.C.B., M.V.O., Governor of New South Wales, and Sir Mungo MacCallum, K.C.M.G., Vice-Chancellor of the Sydney University; and also the Presidents of several societies.

The following member has been honoured during the year:—Sir Alexander MacCormick, K.C.M.G., Knight Commander of the Most Distinguished Order of St. Michael and St. George.

The Council has awarded the Clarke Memorial Medal to Andrew Gibb Maitland, F.G.S.

In connection with the visit of their Royal Highnesses, the Duke and Duchess of York to Australia, an Address of Welcome from the Society was presented to their Royal Highnesses at Government House, Sydney, on the 28th March, 1927:—

"To Their Royal Highnesses the Duke and
Duchess of York.

"May it please your Royal Highnesses,—

"We, the Members of the Royal Society of New South Wales, an offspring of the illustrious Mother Society, which has so long enjoyed the privilege of Royal patronage, desire to approach your Royal Highnesses with our most respectful and cordial greetings on the occasion of this the first visit of your Royal Highnesses to Australia.

"This visit, momentous in the history of our Commonwealth will assuredly make for that advancement of

knowledge for which our Society exists, and exert a powerful influence in further strengthening the sympathy and the existing national ties of loyalty and affection which are strongly supported by the bonds of science between the Motherland and this portion of her Dominions.

"We also desire to express our earnest hope that the memory of this visit will ever be to your Royal Highnesses a source of extreme satisfaction and joy, and we tender our most sincere good wishes for your health and happiness.

"Signed on behalf and in the name of the Royal Society of New South Wales.

"W. G. Woolnough, President."

Sydney, March, 1927.

H. G. Smith Memorial Fund.—The subscribers to the H. G. Smith Memorial Fund, at their final meeting, held on March 15th, 1927, resolved to adopt the following recommendation to the General Committee:—

"That the accumulated funds collected by the Smith Memorial Committee be handed over to the Australian Chemical Institute, to found a Money Prize, to be awarded annually with the Smith Memorial Medal."

The Hon. Treasurer of the Fund, Professor H. G. Chapman, was also authorised to hand over the money in hand (£215) to the Australian Chemical Institute, under a Deed of Trust.

J. H. Maiden Memorial.—At a public meeting, convened by the Royal Society of New South Wales, and held at the Society's House, 5 Elizabeth Street, on the 12th August, 1926, it was decided to perpetuate the memory of the late Joseph Henry Maiden, Government Botanist and Director of the Botanic Gardens, Sydney. The hope of the Committee is that sufficient money may be raised to enable a Memorial Kiosk or Pavilion to be erected in the

Botanic Gardens, to the memory of one who was an outstanding figure in the scientific life of Australia and scientific progress generally.

Sydney Observatory.—Concerning the suggested closing of the Sydney Observatory, a letter was received from the Premier's Department, to the effect that the Observatory will be continued under its present control until the retirement of the Government Astronomer, Professor W. E. Cooke, after which it will be transferred to the administration of Mr. James Nangle, O.B.E., F.R.A.S., Superintendent of Technical Education. The President, as a member of the Board of Visitors to the Sydney Observatory, stated that it was understood the determination of time and the photography of the zone of the southern heavens, allotted to Sydney, was to be continued. Mr. Nangle took over the duties at the Observatory on 1st September, 1926.

The donations to the Library have been as follows:—1507 parts, 52 volumes, 34 reports, 5 calendars, and 5 maps.

The President announced that the following Popular Science Lectures would be delivered this Session:—

June 16—"A Glance at Japan," by R. H. Cambage, C.B.E., F.L.S.

July 21—"Earth Waves and Earth Ripples," by Edgar H. Booth, M.C., B.Sc., F.Inst.P.

August 18—"Some Observations on Disease in Plants," by R. J. Noble, M.Sc., B.Sc.Agr., Ph.D.

September 15—"What Makes a Good Food," by Professor H. G. Chapman, M.D.

It was announced that the Council had awarded the Clarke Memorial Medal to Andrew Gibb Maitland, F.G.S.

The President announced that an Address of Welcome had been presented, on behalf of the Royal Society of New South Wales, to their Royal Highnesses the Duke and Duchess of York, on 28th March, 1927.

The following donations were laid upon the table:—239 parts, 11 volumes, and 6 reports.

The President announced that a letter had that day been received from Dr. W. F. Burfitt, offering the Society £500 for the foundation of a prize, to be awarded annually by the Council, at its discretion, to the person resident in Australia or New Zealand who, in its opinion, has done the most meritorious work in the cause of science during the year. This most generous offer was referred to the Council.

The President, Dr. W. G. Woolnough, delivered his address.

A ballot was then taken, and the following were elected officers and members of Council for the coming year:—

President:

Prof. J. DOUGLAS STEWART, B.V.Sc., M.R.C.V.S.

Vice-Presidents:

J. NANGLE, O.B.E., F.R.A.S.
C. A. SUSSMILCH, F.G.S.
C. ANDERSON, M.A., D.Sc.
W. G. WOOLNOUGH, D.Sc., F.G.S.

Hon. Treasurer:

Prof. H. G. CHAPMAN, M.D.

Hon. Secretaries:

R. H. CAMBAGE, C.B.E., F.L.S.
R. GREIG-SMITH, D.Sc., M.Sc.

Members of Council:

J. J. C. BRADFIELD, D.Sc., Eng., M.E., M.Inst.C.E.
R. W. CHALLINOR, F.I.C., F.C.S.
E. CHEEL.
Prof. L. A. COTTON, M.A., D.Sc.
Prof. C. E. FAWSITT, D.Sc., Ph.D.
Prof. J. KENNER, Ph.D., D.Sc., F.R.S.
R. J. NOBLE, M.Sc., B.Sc.Agr., Ph.D.
Rev. E. F. PIGOT, S.J., B.A., M.B.
W. POOLE, M.E., M.Inst.C.E., M.I.M.M., etc.
Prof. O. U. VONWILLER, B.Sc., F.Inst.P.

Dr. W. G. Woolnough, the out-going President, then installed Professor J. Douglas Stewart as President for the ensuing year, and the latter briefly returned thanks.

On the motion of Professor L. A. Cotton, seconded by Mr. W. Poole, a hearty vote of thanks was accorded to the retiring President for his valuable address.

Dr. Woolnough briefly acknowledged the compliment.

JUNE 1, 1927.

The four hundred and sixty-ninth General Monthly Meeting was held at the Society's House, 5 Elizabeth St., at 8 p.m.

Professor J. Douglas Stewart, President, in the chair.

Twenty-five members and two visitors were present.

The Minutes of the preceding meeting were read and confirmed.

The certificates of eight candidates for admission as ordinary members were read: six for the second time and two for the first time.

The following gentlemen were duly elected ordinary members of the Society:—Horace Finnemore, William Henry Love, William Lindsay Price, Claude Witherington Stump, Alfred Radcliffe-Brown, and Herbert John Wilkinson.

Letters were read from Mrs. T. Fiaschi and Mrs. W. J. Newbigin, expressing thanks for the Society's sympathy in their recent bereavements.

The President announced that Mr. R. H. Cambage, C.B.E., F.L.S., would deliver a Popular Science Lecture entitled, "A Glance at Japan," in the Society's Hall, on Thursday, 16th June, 1927, at 8 p.m.

The following donations were laid upon the table:—150 parts, 11 volumes, and 9 reports.

THE FOLLOWING PAPERS WERE READ:

1. "A Critical Examination of *Eucalyptus dives* and the occurrence of a number of varieties thereof as deter-

mined by chemical analysis of the Essential Oils," Part I., by A. R. Penfold, F.A.C.I., F.C.S., and F. R. Morrison, A.A.C.I., F.C.S.

The paper was read by Mr. Penfold, and remarks were made by Messrs. E. Cheel, M. B. Welch, F. R. Morrison, and the President.

2. "The Preparation of Tetramethylethylene," by J. C. Earl, D.Sc., Ph.D.

Remarks were made by Professors J. Kenner and C. E. Fawsitt, and Mr. R. W. Challinor.

3. "Protogenesis and Ex-Nuptial Natality in Australia," by Sir George Knibbs, C.M.G., F.R.A.S.

In the absence of the author in Melbourne, this paper was taken as read, on the understanding that Professor H. G. Chapman would give a synopsis of it at the next meeting.

EXHIBIT:

Mr. J. Nangle, O.B.E., F.R.A.S., exhibited one of the photographic plates made at the Sydney Observatory, in the preparation of the Great Photographic Star Catalogue, and explained the methods and precautions employed in the preparation of Astrophotographs and the uses to which they are put.

Remarks were made by the President.

JULY 6th, 1927.

The four hundred and seventieth General Monthly Meeting was held at the Society's House, 5 Elizabeth Street, at 8 p.m.

Professor J. Douglas Stewart, President, in the chair.

Thirty-two members and six visitors were present.

The Minutes of the preceding meeting were read and confirmed.

The President announced the death of Mr. T. W. Keele, who was elected a member in 1876.

A letter was read from Mrs. T. W. Keele, expressing thanks for the Society's sympathy in her recent bereavement.

The certificates of five candidates for admission as ordinary members were read: two for the second, and three for the first time.

The following gentlemen were duly elected ordinary members of the Society:—Geoffrey Saunders Currey, and William Keith Inglis.

The President announced that the £500 referred to at the May meeting, from Dr. Walter Burfitt, as a Prize Fund, had been duly received.

The President announced that Mr. Edgar H. Booth, M.C., B.Sc., F.Inst.P., would deliver a Popular Science Lecture entitled, "Earth Waves and Earth Ripples," on Thursday, 21st July, 1927.

The following donations were laid upon the table:—171 parts, 10 volumes, and 5 reports.

THE FOLLOWING PAPERS WERE READ:

1. "Observations on Rodents and Their Parasites," by J. W. Fielding (communicated by Prof. H. G. Chapman, M.D.).

2. "Swelled Head in Merino Rams," by the late Sydney Dodd, F.R.C.V.S., D.V.Sc., communicated and read by Professor J. Douglas Stewart.

Remarks were made by Messrs. R. Grant and R. M. C. Gunn.

3. "Descriptions of Nine New Species of Eucalyptus," by W. F. Blakely.

4. "The Essential Oil of *Eucalyptus Bakeri,*" by A. R. Penfold, F.A.C.I., F.C.S.

Remarks were made by Messrs. R. T. Baker, H. Finnemore, R. W. Challinor, A. D. Olle, and W. F. Blakely.

Professor Chapman gave a synopsis of Sir George Knibbs' paper on "Protogenesis and Ex-Nuptial Natality in Australia," which was presented at the previous meeting.

EXHIBIT:

Mr. J. Nangle, O.B.E., F.R.A.S., exhibited a photo negative of the wonderful Star Cluster, Omega Centauri.

AUGUST 3, 1927.

The four hundred and seventy-first General Monthly Meeting was held at the Society's House, 5 Elizabeth St., at 8 p.m.

Professor J. Douglas Stewart, President, in the chair.

Twenty-nine members and two visitors were present.

The Minutes of the preceding meeting were read and confirmed.

The President announced the deaths of Dr. E. W. Ferguson, elected in 1920, and Mr. Ebenezer MacDonald, elected in 1878.

A letter was read from Professor Liversidge, thanking the Society for greetings sent from members at the Annual Dinner.

A letter was read from Mrs. E. W. Ferguson, expressing thanks for the Society's sympathy in her recent bereavement.

The certificates of three candidates for admission as ordinary members were read for the second time.

The following gentlemen were duly elected ordinary members of the Society:—Reginald Montague Gunn, Frederick Duncan McMaster, and Ian Clunies Ross.

The President announced that Dr. R. J. Noble, B.Sc.Agr., Ph.D., would deliver a Popular Science Lecture entitled, "Some Observations on Disease in Plants," on Thursday, 18th August, 1927.

The following donations were laid upon the table:—4 volumes, 145 parts, 8 reports, and 6 maps.

THE FOLLOWING PAPERS WERE READ:

1. "Rigorous Analysis of the Phenomena of Multiple Births," by Sir George Knibbs, C.M.G., etc.

In the absence of the author in Melbourne, this paper was taken as read.

2. "Studies in the Inheritance of Resistance in Leaf Rust, *Puccinia anomola* Rostr. in crosses of Barley, I." by Acting-Professor W. L. Waterhouse, M.C., B.Sc.Agr.

Remarks were made by Mr. R. W. Challinor and the President.

3. "The Wood Structure of Some Species of Kauri" (Agathis spp.), by M. B. Welch, B.Sc., A.I.C.

Remarks were made by Messrs. A. S. LeSouef, E. Cheel, A. R. Penfold, and the President.

This year being the bicentenary of the death of Sir Isaac Newton, a lecture, entitled "Newton," was given by Professor O. U. Vonwiller B.Sc., F.Inst.P.

SEPTEMBER 7, 1927.

The four hundred and seventy-second General Monthly Meeting was held at the Society's House, 5 Elizabeth St., at 8 p.m.

Professor J. Douglas Stewart, President, in the chair.

The Minutes of the preceding meeting were read and confirmed.

The death was announced of Dr. A. J. Brady, who was elected a member in 1876.

The death was also announced of Dr. Robert Greig-Smith, one of the Honorary Secretaries of the Society, and the following motion, which had been carried by the Council, was endorsed by the meeting, the members standing:—"The Council of the Royal Society of New South Wales desires to place on record in the Minutes its deep sorrow at the death of the Honorary Secretary, Dr. Robert Greig-Smith, and to express its high appreciation of his many personal services to this Society, and the value of the bacteriological work which he carried out in the interests of Science in Australia."

A letter was read from Mrs. R. Greig-Smith, expressing thanks for the Society's sympathy in her recent bereavement.

The President announced the sale of the Society's House for the sum of £28,000 cash. He also announced that it was proposed to take steps, in conjunction with kindred societies, to arrange for the building of a Science House on a block of land which the Government had presented, free of charge, for the purpose of housing scientific and kindred bodies, at the corner of Gloucester and Essex Sts.

The President announced that Professor H. G. Chapman, M.D., would deliver a Popular Science Lecture, entitled, "What Makes a Good Food," in the Society's Hall, on Thursday, 15th September, 1927.

The following donations were laid upon the table:—10 volumes, 183 parts, 6 reports, and 1 map.

THE FOLLOWING PAPER WAS READ:

1. "The Essential Oils of *Eucalyptus micrantha* and *E. haemastoma*," Part I., by A. R. Penfold, F.A.C.I., F.C.S., and F. R. Morrison, A.I.C., F.C.S.

Remarks were made by Messrs. R. W. Challinor and R. H. Cambage.

The President announced that Dr. R. J. Noble, B.Sc.Agr., Ph.D., would deliver a Popular Science Lecture entitled, "Some Observations on Disease in Plants," on Thursday, 18th August, 1927.

The following donations were laid upon the table:—4 volumes, 145 parts, 8 reports, and 6 maps.

THE FOLLOWING PAPERS WERE READ:

1. "Rigorous Analysis of the Phenomena of Multiple Births," by Sir George Knibbs, C.M.G., etc.

In the absence of the author in Melbourne, this paper was taken as read.

2. "Studies in the Inheritance of Resistance in Leaf Rust, *Puccinia anomola* Rostr. in crosses of Barley, I." by Acting-Professor W. L. Waterhouse, M C., B.Sc.Agr.

Remarks were made by Mr. R. W. Challinor and the President.

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Remarks were made by Messrs. R. W. Challinor and R. H. Cambage.

A lecturette entitled, "The Mint Sediment Test for Milk" (Thomson) was given by R. Grant, F.C.S.

OCTOBER 5, 1927.

The four hundred and seventy-third General Monthly Meeting was held at the Society's House, 5 Elizabeth St., at 8 p.m.

Professor J. Douglas Stewart, President, in the chair.

Thirty-two members and two visitors were present.

The Minutes of the preceding meeting were read and confirmed.

The death was announced of Professor A. Liversidge, in England, the Society's oldest member. The Society was represented at the funeral by Sir Edgeworth David.

The following motion, which had been carried by the Council, was endorsed by the meeting, the members standing:—"That the members of the Council of the Royal Society of New South Wales desire to place on record in the Minutes their deep sorrow at the death of their esteemed colleague, Professor Archibald Liversidge, and to express their very high appreciation of the great services he rendered in the cause of science in Australasia, and more particularly to this Society."

A letter was read from Mrs. A. J. Brady expressing thanks for the Society's sympathy in her recent bereavement.

The certificate of one candidate for admission as an ordinary member was read for the first time.

The President announced that Professor O. U. Vonwiller had been appointed Honorary Secretary, to fill the vacancy caused by the death of Dr. R. Greig-Smith.

The President announced that Dr. Rudolf Krahmann, of the Technical University, Berlin, would deliver a lec-

ture entitled, "Subterranean Survey by Geophysical Methods," in the Society's Hall, on Monday, 31st October, 1927.

The following donations were laid upon the table:—88 parts, 3 reports, and 1 catalogue.

THE FOLLOWING PAPER WAS READ:

1. "The Vertical Growth of Trees," No. II, by R. H. Cambage, C.B.E., F.L.S.

Remarks were made by Messrs. E. Cheel, M. B. Welch, and R. T. Baker.

A lecturette entitled, "Agriculture and Research in Java," was given by Professor R. D. Watt, M.A., B.Sc.

EXHIBITS:

Mr. R. H. Cambage exhibited a photograph of a young Eucalyptus tree from Corella River, north of Cloncurry, Queensland, which had been killed by frost near Sydney. The species was described by him, without flowers, in these Proceedings, 1915, 49, but not named. The author now proposed the name of *E. tropica* for the species.

Also two seedlings of *Acacia crassiuscula* in a four-inch pot, in which they had been growing for seven years. The plants, raised from seeds produced by pot-plant, were six feet high, and bearing young pods. The only attention they had received was regular watering, and they had produced seeds for several years.

NOVEMBER 2, 1927.

The four hundred and seventy-fourth General Monthly Meeting was held at the Society's House, 5 Elizabeth St., at 8 p.m.

Professor J. Douglas Stewart, President, in the chair.

Thirty-one members and four visitors were present.

The Minutes of the preceding meeting were read and confirmed.

The certificate of one candidate for admission as an ordinary member was read for the second time.

The following gentleman was duly elected an ordinary member of the Society:—Alfred James Shearsby.

The following donations were laid upon the table:—107 parts, 4 volumes, and 4 reports.

THE FOLLOWING PAPERS WERE READ:

1. "The Essential Oils of Two Species of Baeckea," by A. R. Penfold, F.A.C.I., F.C.S.

Remarks were made by Mr. E. Cheel.

2. "The Moisture Content of Some Eucalyptus Woods," by M. B. Welch, B.Sc.

Remarks were made by Professor C. E. Fawsitt.

3. "The Cause of Blueing in Red Roses," by G. S. Currey, F.C.S.

EXHIBIT:

Mr. E H. Booth exhibited Cinematograph Records of Heart-Beats, obtained by Stethoscope and Hot-wire Microphone.

Messrs. Parke, Davis & Son gave a cinema demonstration on the preparation of Biological Products.

DECEMBER 7, 1927.

The four hundred and seventy-fifth General Monthly Meeting was held at the Society's House, 5 Elizabeth St., at 8 p.m.

Professor J. Douglas Stewart, President, in the chair.

Forty-one members and three visitors were present.

The Minutes of the preceding meeting were read and confirmed.

The following donations were laid upon the table:—182 parts, 5 reports, 6 volumes, and 3 calendars.

THE FOLLOWING PAPERS WERE READ:

1. "The Determination of Minute Quantities of Metals in Biological Material," Part I., The Determination of Lead in Urine, by H. B. Taylor, M.C., D.Sc., F.A.C.I.

Remarks were made by Professor Fawsitt, Drs. H. S. H. Wardlaw, and R. K. Murphy, and R. W. Tannahill.

2. "The Essential Oil from the Timber of Rosewood" (*Dysoxylon Fraseranum*), by A. R. Penfold, F.A.C.I, F.C.S.

3. "Proof of the Laws of Twin-Births," by Sir George Knibbs, C.M.G., M.Inst.Int.d.Stat., etc.

In the absence of the author, this paper was taken as read.

4. "Some Mechanical Properties of Australian Grown *Pinus insignis*" (*P. radiata*), with notes on the wood structure, by M. B. Welch, B.Sc., A.I.C.

In the absence of the author, this paper was read by Mr. R. H. Cambage.

5. "Petrological Notes on some New South Wales Alkaline Basic Rocks," by Assist.-Professor W. R. Browne, D.Sc.

6. "On Some Metamorphosed Dolerites from Broken Hill," by Assist. Professor W. R. Browne, D.Sc.

7. "Descriptions of Four New Species of Boronia," with notes on certain other species, by E. Cheel.

A lecturette, on the "Development of Liver Fluke, (*Faciola hepatica*)," was given by I. Clunies Ross, B.V.Sc., with cinema views by Visual Education Limited.

The President announced that this would possibly be the last meeting the Society would hold in the hall, as, although the building would continue to be occupied by the Society until the end of the year, 1928, the hall would probably have to be vacated very early in the year 1928.

GEOLOGICAL SECTION.

ABSTRACT OF THE PROCEEDINGS

OF THE

GEOLOGICAL SECTION.

Annual Meeting, March 18, 1927.

Dr. W. G. Woolnough was in the chair, and nine members and fourteen visitors were present.

Dr. Woolnough and Mr. G. D. Osborne were elected Chairman and Honorary Secretary respectively for the year.

EXHIBITS:

1. By Mr. L. L. Waterhouse: Photographs and specimens illustrating the change from fresh rock through weathered material into soil in a columnar basalt quarry near Oberon.

2. By Rev. R. T. Wade: (a) Specimen of Hawkesbury sandstone, from 1½ miles from Dee Why, the joint-faces of which were coated with pyrites crystals; (b) Specimen of shale from Condobolin, containing *Taeniopteris* and *Thinnfeldia odontopteroides.*

Mr. G. A. V. Stanley gave an address, illustrated by lantern slides, dealing with the geological and other aspects of the Great Barrier Reef.

April 12, 1927.

Dr. W. G. Woolnough was in the chair, and seven members and five visitors were present.

EXHIBITS:

1. By Mr. L. L. Waterhouse: Nodular celestite from Brewarrina, N.S.W., believed to be concretionary in origin.

2. By Mr. Clark: Specimen of flint with fossil shell, dredged from Newcastle Harbour. This was evidently brought as ballast from Europe.

3. By Mr. G. D. Osborne: Specimen of porphyritic basalt (Tertiary), from Bunbury, W.A., showing well-developed crystals of augite, some of which are twinned.

Assist. Professor W. R. Browne addressed the Section on "Some Examples of the Operation of Late-magmatic Processes". He summarised the existing knowledge concerning the last phases in the evolution of igneous rocks, and discussed numerous Australian examples where late-magmatic processes had been active.

Discussion was contributed by Professor Cotton, Dr. Woolnough, Messrs. L. L. Waterhouse and G. D. Osborne.

May 10, 1927.

Dr. Woolnough was in the Chair, and eight members and nine visitors were present.

EXHIBITS:

1. By the Mining Museum: (a) Specimens of chrysotile from Rhodesia, showing intersection and forking of veins; (b) Non-indurated, fossiliferous calcareous shale of Cambrian age from Esthonia.

2. By Professor L. A. Cotton: Series of specimens from Mt. Isa, Queensland. This exhibit was discussed by Messrs. Browne, Osborne, Woolnough and Waterhouse.

3. By Assist. Professor W. R. Browne: (a) Contact metamorphic quartzite with fossils converted into wollastonite, from Cox's River, Hartley; (b) Chert pebble from Glenbrook gravels, containing *Glossopteris*.

4. By Mr. Arthur Coombe: Photographs of Vesuvius Crater.

Professor L. A. Cotton gave an address upon the general vulcanology and the oil-fields of Java, using a suite of specimens and lantern slides to illustrate his remarks.

Remarks were made by Dr. Woolnough, Dr. Browne, and Mr. Clark.

June 13, 1927.

Professor Cotton was in the chair, and eight members were present.

Dr. Woolnough was congratulated upon his appointment as Geological Adviser to the Federal Government, and his resignation as Chairman of the Section was received with regret.

Professor Cotton was unanimously elected as Chairman.

EXHIBITS:

1. By Rev. R. T. Wade: (a) Specimens of sandstone from near Manly Trig. Station, which were indurated, due to a dyke-intrusion; (b) Specimen of sandstone with barytes and plant remains.

2. By the Mining Museum: (a) Kernite, a recently discovered borate of soda, from Mohave, California; (b) Beryl crystals in native bismuth, from Torrington, N.S.W.; (c) Doubly-terminated quartz crystals from the 1000ft. level, Zinc Corporation Mine, Broken Hill; (d) Galena and chalcopyrite, with crystallised quartz, from same locality.

3. By Dr. W. R. Browne: (a) Fossiliferous shale similar to that of Talbragar, from Jeridgeree, near Mudgee; (b) Magnetite beach-sand from the Solomon Islands; (c) Leucite-basalt, from Vesuvius; (d) Portion of a fossil, *Palaeaster*, from the Breakwater, Naval College, Jervis Bay; (e) Breccia or tillite, from the Upper Marine Series, Little Hartley.

Mr. C. A. Sussmilch addressed the Section on the Geology of the Canadian Cordillera, giving a general account of the geomorphology, stratigraphy, and geological history of the region.

Remarks were made by Professors Cotton and Browne, and Messrs. Dun, Taylor, and Wade.

July 12, 1927.

Professor Cotton was in the chair, and five members and five visitors were present.

EXHIBITS:

1. By the Mining Museum: (a) Lode tin-ore, crystallised tin stone in topaz-rock, green tourmaline, and quartz-porphyry; all from Mt. Bischoff, Tasmania; (b) Osmiridium, from Tasmania; (c) Zinc-lead sulphide, from Hercules Mine, Tasmania.

2. By Mr. L. L. Waterhouse: Extensive series of specimens illustrating the Mining Fields of Stanley River, Heemskirk, and North-eastern Tasmania.

Mr. L L. Waterhouse addressed the Section upon "Some Occurrences of Tin and Osmiridium in Tasmania." He gave a general account of the occurrences of these minerals in Tasmania, and then described in some detail the mining fields of the West Coast, and also spoke concerning King, Flinders, and Cape Barren Islands.

Remarks were made by Professor Cotton and Mr. G. D. Osborne.

August 9, 1927.

Professor Cotton was in the chair, and five members and one visitor were present.

EXHIBITS:

1. By Mr. G. D. Osborne: A specimen from the Main Glacial Beds of Seaham, showing brecciated varve-rock intimately associated with tuff.

Dr. Charles Anderson addressed the Section on the Fossil Marsupials of Australia, pointing out their relationship to similar fossil remains in other parts of the world, and to the present-day marsupial fauna.

September 13, 1927.

Professor Cotton was in the Chair, and there were four members and two visitors present.

EXHIBITS:

1. By Professor L. A. Cotton: (a) Samples of oil collected from a natural seepage, south of Murchison, N.Z.; (b) Rocks from the Jeppoe Oil Series, Java.

2. By the Mining Museum: (a) Ellipsoidal concretion in massive Hawkesbury sandstone; (b) Desert pebbles coated with iron pyrites from Central Australia; (c) Polished banded sedimentary rock from Mt. Isa; (d) Cambrian limestone, from China.

3. By Rev. R. T. Wade: Fossils. from the Brookvale Quarry, comprising remains of fish and insects.

4. By Mr. G. D. Osborne: (a) Specimens of tuff and conglomerate, from the Upper Marine Series, Singleton; (b) Greta conglomerate from the Loder Bore, near Singleton; (c) Specimen of Miocene limestone, from Taranaki, N.Z. This is associated with oil-bearing strata, near New Plymouth.

During a discussion of the exhibits, Mr. Nason Jones, of the Anglo-Persian Oil Company, spoke to the Section upon some of the conditions of oil-occurrence in Persia.

October 21, 1927.

Professor Cotton was in the chair, and nine members and two visitors were present.

A communication from Prof. Davidson Black, of Peking Medical College, regarding "Tertiary Man in Asia," was read by the Secretary. An abstract of this follows:—

Tertiary Man in Asia—The Chou Kou Tien Discovery.

A rich fossiliferous deposit at Chou Kou Tien, 70 li to the southwest of Peking, was first discovered in 1921 by Dr. J. G. Andersson and later surveyed and investigated by Dr. O. Zdansky. As a result of this research, Dr. Andersson announced that, in addition to the mammalian groups recorded from this site, there have been identified representatives of the *Cheiroptera*, one cynopithecid and finally two extremely interesting specimens, namely, one premolar and one molar tooth of a species which cannot otherwise be named than *Homo* (?) *sp.*

The Chou Kou Tien fauna was originally thought to be possibly of Upper Pliocene age, but later research may put it down as early Pleistocene: but whichever is right, the outstanding fact remains that, for the first time on the Asiatic continent north of the Himalayas, archaic hominid fossil material has been recovered accompanied by definite geological data.

One of the teeth recovered is a right upper molar, probably the third, whose relatively unworn crown presents characters which appear to be essentially human. The posterior moiety of the crown is narrow and the roots appear to be fused. The other tooth is probably a lower anterior premolar of which the crown only is preserved. The latter also is practically unworn and appears in the photograph to be essentially bicuspid in character, a condition usually to be correlated with a reduction of the upper canine.

The Chou Kou Tien molar tooth, though unworn, would seem to resemble in general features the specimen purchased by Haberer in a Peking native drug shop and subsequently described in 1903 by Schlosser, who considered it in all probability to be Tertiary in age, and provisionally designated it as *Homo* (?) *anthropoide* (?).

It is now evident that at the close of Tertiary or the beginning of Quarternary time, man or a very closely related anthropoid actually did exist in eastern Asia. This is of great importance, for about this time lived in Java Pithecanthropus, at Piltdown Eoanthropus, and but very shortly after at Mauer the man of Heidelberg. All these forms were thus practically contemporaneous with one another and occupied regions equally far removed respectively to the east, to the south-east and to the west from the central Asiatic plateau which it has been shown elsewhere most probably coincides with their common dispersal centre. The Chou Kou Tien discovery furnishes one more link in the already strong chain of evidence supporting the hypothesis of the central Asiatic origin of the *Hominidiae*.

EXHIBITS AND DISCUSSION:

1. By Assist. Professor Browne: (a) Bipyramidal quartz from weathered granite-porphyry near the Cotter Dam, Federal Capital Territory; (b) Banded Calcareous Sedimentary rock, from Elsmore, N.S.W.

2. By Miss I. A. Brown: A series of specimens of garnet-bearing dyke-rocks from near Moruya, South Coast, N.S.W. This exhibit was discussed by Messrs. Sussmilch, Cotton, Browne, and Osborne.

3. By Mr. T. Hodge Smith: Photographs of a meteorite, containing silicate minerals, from Manaia Hills, Sth. Australia.

4. By Mr. W. S. Dun: (a) Diatomaceous earth from near Coonabarabran, containing fossil fish; (b) Specimen of Eurydesma, from Wollongong, N.S.W.

5. By the Mining Museum: A series of eclogites from various parts of New South Wales, and some basalt of *Eurydesma,* from Wollongong, N.S.W.

6. Mr. W. Poole reported having acquired some unique specimens of native gold from Woodlark Island. He also exhibited pebbles from river gravels in an old channel of an ancestor of the present Macquarie River, and described the physiography of the Macquarie River, in the neighbourhood of Warren.

7. By Mr. G. D. Osborne: Specimens of cone-in-cone structure, in shales from Camden and Newcastle, the ages of the rocks being Triassic and Permo-Carboniferous respectively.

November 18, 1927.

Dr. W. R. Browne was in the chair, and six members and three visitors were present.

Professor W. N. Benson, of Otago University, was cordially welcomed by the Chairman.

EXHIBITS:

1. By Mr. G. D. Osborne: (a) Cross-section of a stem of *Vertebraria*, from Baker's Quarry, East Maitland; (b) Large fossil leaf, showing the characteristic venation of *Glossopteris*, but possessing unique features concerning the form of the base of the leaf. From the Newcastle Coal Measures at Joadja.
2. By Mr. Clark: (a) Fossil fish, from shale band in Hawkesbury sandstone, near St. Ignatius' College; (b) Specimen of some type of fructification in plant fossil.

Mr. C. A. Sussmilch gave an account of the Geology of the Port Stephens Area. He pointed out that both Burindi and Kuttung rocks occurred in the area, but the details of sequence and structure were obscured by the prevalence of wind-blown sand and swamps. Intermediate and acid lavas occur, and some subordinate sedimentary rocks. The analyses of the lavas give interesting details concerning the order of extrusion and the magmatic relationships.

Remarks were made by Professors Benson and Browne, and Messrs. Waterhouse, Clark and Osborne.

Professor Benson gave a short address to the Section upon the Upper Palaeozoic rocks of the South Island of N.Z., and traced the orogenic movements which affected the South Island in post-Palaeozoic time.

SECTION OF AGRICULTURE.

ABSTRACT OF THE PROCEEDINGS

OF THE

SECTION OF AGRICULTURE.

Annual Meeting, June 6, 1927.

Mr. A. D. Ollé presided.

The election of officers resulted as follows:—*Chairman*: A. D. Ollé, F.C.S.; *Vice-Chairman*: Professor R. D. Watt; *Honorary Secretaries*: P. Hindmarsh, M.A., B.Sc.Agr., R. J. Noble, Ph.D., M.Sc., B.Sc.Agr.; *Committee*: E. A. Southee, O.B.E., M.A., B.Sc., B.Sc.Agr., W.L. Waterhouse, M.C., B.Sc.Agr., D.I.C., H. J. Hynes, M.Sc., B.Sc.Agr., E. N. Ward.

Mr. Ward, Superintendent of the Botanic Gardens, Sydney, addressed a small meeting on various aspects of Horticulture in Great Britain. The address included many observations made during Mr. Ward's recent trip abroad, and was of particular interest.

November 21, 1927.

Mr. A. D. Ollé presided.

Professor R. D. Watt addressed the meeting on "The International Institute of Agriculture and the 1927 Rome Wheat Conference".

The lecturer first gave an interesting résumé of agricultural conditions in Italy and of the special features of the organisation of the International Institute of Agriculture.

The conference was attended by 82 official delegates representing 34 countries, and was considered the most important conference dealing with wheat which had ever been held.

The proceedings of conference were held under three divisions—(a) Commercial, (b) Cultivation and Diseases, (c) Breeding and Ecology.

In section (c) special attention was devoted to the questions of breeding for disease resistance and for quality.

SECTION OF INDUSTRY.

ABSTRACT OF THE PROCEEDINGS

OF THE

SECTION OF INDUSTRY.

Officers—Chairman: W. W. L'Estrange; *Honorary Secretary*: R. Greig-Smith, D.Sc., M.Sc.

After the death of Dr. Greig-Smith on 6th August, 1927, Mr. H. V. Bettley-Cooke was appointed Hon. Secretary.

As in 1926, the activities of the Section consisted of visits to industrial establishments.

In all cases, manufacturers gave a cordial welcome to members and went to considerable trouble in explaining their processes and in preparing exhibits.

The following visits were paid:—

June 14th, 1927—Messrs. Bonds Cotton Mills, Wentworthville.

July 12th, 1927—The Federal Match Co., Ltd., Alexandria.

August 9th, 1927—Columbia Graphophone Works (Australia) Ltd., Homebush.

September 21st, 1927—The Australian Glass Co., Waterloo.

October 11th, 1927—Messrs. Wunderlich's Terra Cotta Works, Rosehill.

November 8th, 1927—Messrs. Resch's Brewery, Waterloo.

December 13th, 1927—The Rexonola Phonograph Works, Lilyfield.

SECTION OF PHYSICAL SCIENCE.

ABSTRACT OF PROCEEDINGS

OF THE SECTION OF

PHYSICAL SCIENCE.

Eight meetings were held during the year, the average attendance of members and visitors being 14. The election of officers for the year was held at the May meeting and resulted as follows:

Chairman—Assoc. Professor V. A. Bailey, M.A., D.Phil., F.Inst.P.

Honorary Secretary—G. H. Briggs, B.Sc., Ph.D.

Committee—Major E. H. Booth, M.C., B.Sc., F.Inst.P.; The Rev. Father Pigot, S.J., B.A., M.B.; J. J. Richardson, A.M.I.E.E.; Assoc. Professor Wellish, M.A.; Professor Vonwiller, B.Sc., F.Inst.P.

April 20th, 1927.

Professor Vonwiller in the Chair.

Paper by Dr. G. H. Briggs—"The Straggling of Alpha Particles".

An account was given of the work carried out by the author at Cambridge. The straggling of alpha particles from Radium C was investigated by measuring by the magnetic deflection method the distribution of velocities about the mean emergent velocity when the rays had passed through various thicknesses of mica. With the well-known arrangement of source, slit and photographic plate, the variation in velocity appeared as a broadening of the

deflected band. The deflected and undeflected bands were analysed with a microphotometer—a separate investigation showing that the relation between density and exposure for alpha rays was approximately linear in the range of densities occurring.

The experiments extended over a range of velocities from 0.98 to 0.22 V_0. The rate of increase of the straggling along the range of the alpha particle was a maximum near the beginning of the range as may be predicted from Bohr's theory of the phenomenon, but the amount of straggling was found to be everywhere 1.4 times as great as calculated on that theory. This discrepancy still remains when the straggling is calculated from the theories of the decrease of velocity of alpha particles as given by Henderson and Thomas.

May 18th, 1927.

Professor Bailey in the Chair.

Professor Vonwiller gave an account of Recent Optical Work in Japan. He described briefly the general conditions under which research is carried on, namely, large staff, small number of students and ample supplies of the best apparatus. Much of the work consists of systematic classification of optical spectra produced by various methods of excitation. The work of Kimura and Nakamura in Kyoto on the excitation of the spectra of singly and multiply ionised atoms in strong electric fields produced by powerful arcs was described.

An account was given of the work of Nagaoka in Tokio on the fine structive of the mercury lines, and his theory that this structure is an isotope effect, which may be explained by assuming that some of the protons lie outside the main structure of the nucleus. Nagaoka's claim to have transformed mercury into gold receives some support on such a hypothesis.

Professor Bailey described some recent experiments made by J. Thiband in De Broglie's laboratory in Paris on the diffraction of X rays by ruled glass gratings. A beam of X rays falling at almost grazing incidence on a glass grating of 2,000 lines per cm. produces very sharp diffraction spectra in several orders. From measurements of these the wave length may be calculated and is found to agree with that deduced from experiments made with crystals. The method has been applied to the analysis of gamma rays by replacing the glass grating by a crystal.

June 15th, 1927.

Professor Bailey in the Chair.

Dr. G. H. Briggs gave an account of a redetermination by the magnetic deflection method of $H\rho$ or MV/E for alpha particles from radium C. The value of $H\rho$ was found to be 3.993×10^5 E.M. Units, and from the value of E/M deduced from electrochemical data, taking into account the relativity increase of mass of the alpha particle the velocity was found to be 1.923×10^9 cm. per second. The corresponding values found by Rutherford and Robinson in 1914 were 3.983×10^5 and 1.922×10^9. Results were also found for the velocities of alpha particles from Thorum C and C^1. A table was shown giving the velocities of particles from other radio active substances deduced from Geiger's measurements of the ranges and the author's work on the decrease of velocity of alpha particles from radium C.

Professor Bailey described some of the recent advances in X rays. Deviations from the Bragg's law of reflection from a crystal surface were studied by Siegbahn, Hjalmar and others who were thus led to the discovery of refraction of X rays and so to the existence of a refractive index for such rays. The phenomenon of "anomalous" dispersion was also found to exist.

Mark and Szilard have discovered that a suitably selected crystal surface may be used either as a polariser or an analyser for X rays, a result which is full of promise for future research on the nature and properties of such radiation.

July 20th, 1927.

Professor Bailey in the Chair.

Dr. T. Iredale addressed the meeting on "Some Aspects of Surface Tension and Adsorption".

The adsorption of vapours on liquid surfaces may be measured indirectly by surface tension methods. This was foreshadowed fifty years ago by Willard Gibbs, but only recently put to an experimental test. In particular on a mercury surface adsorption of vapours is very slight and the films must be extremely attenuated, only one molecule in thickness. Sometimes such adsorption is irreversible and quite thick films can be obtained with saturated vapours. This is an extension in part of Langmuir's work on surface tension.

August 17th, 1927.

Mr. A. B. Hector read a paper on "A Reconciliation of the Emission Theory of Light with that of Polarisation".

It was maintained that light consists of streams of electrons moving in vortices or spirals and that the interference of light is explained on this hypothesis, thus reconciling the emission and the undulatory theories of light. It was claimed that this hypothesis anticipates the work of Oulenbeck and Goudsmit on the spinning electron.

Criticism was made by Professor Vonwiller and the secretary. It was pointed out that the assumptions made were inconsistent with experiment and that the explanations of observed phenomena were not adequate, and that

the spin attributed to the electrons of atoms by Oulenbeck and Goudsmit is quite different from that described by the author.

September 21st, 1927.

Professor Bailey in the Chair.

Mrs. G. H. Briggs gave an account of the development of the new quantum mechanics.

The first form of the new quantum theory was put forward by Heisenberg in 1925. He postulated that for a single degree of freedom the state of the atom is to be defined as a function of two sets of parameters instead of the single set which appears in the classical theory. Heisenberg showed that as a consequence of the energy equation $E_n - E_m = h\nu_{nm}$ we must expect that quantum quantities will not obey the commutative law, i.e., in general, X.Y. is not equal to Y.X.

This work has been developed by Born, Jordan and Dirac and others. The new theory enables us to obtain all the results of the old theory and in addition clears up many difficulties. It is also more logical since it can be developed from only two fundamental postulates. Some of the mathematical formulæ are clumsy, but this objection has been largely removed by Schrödinger's work. The new theory can not yet give any mechanical picture of quantum processes.

October 19th, 1927.

Professor Bailey in the Chair.

Mr. W. G. Baker gave an account of his work on the Refraction of Short Electromagnetic Waves in the Upper Atmosphere.

The upper atmosphere consists mainly of helium at great heights, and at heights of the order of 100 km. mainly of nitrogen. Many physical phenomena indicate the

presence of strong ionisation in some region of the upper atmosphere, for example, the aurora borealis and the variations of the earth's magnetic field.

An electromagnetic wave travelling through such an ionised layer will act as if the dielectric constant were reduced, and consequently a ray may bend around and return to earth. For any assumption of ionisation distribution, the ray paths may be calculated and comparisons can be made with experimental results.

November 16th, 1927.

Professor Bailey in the Chair.

Mr. J. Bannon, B.Sc., read a paper on the "Motion of Electrons through Ethylene".

Using a Townsend ionisation chamber the diffusion of streams of electrons moving under an electric force Z through ethylene at a pressure p was determined with and without a horizontal magnetic field and thereby the values of W, the drift velocity of electrons through ethylene, and k, the ratio of the mean kinetic energy of an electron to that of an ethylene molecule, were determined for various values of Z/p. Knowing the values of k and W, the values of U, the agitational velocity and L, the mean free path of an electron in ethylene were calculated. The L — U curve is somewhat similar to that for oxygen, having a maximum and minimum. It intersects the hydrogen curve at three points. Research with ethylene proved to be tedious owing to the rapid decomposition of the gas, either as the result of exposure to ultra violet light or electron collision, and also owing to matter which settled on the gold reflector absorbing or scattering the ultra violet light.

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